THE DESIGN AND DEVELOPMENT OF A MANUAL TOOL FOR DIE CUTTING AND EMBOSSING ON PAPER

(Case of study for the company MR PRINT SDN BHD in Kuala Lumpur, Malaysia)

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EAFIT UNIVERSITY
PRODUCT DESIGN ENGINEERING
MEDELLIN, COLOMBIA
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Graduation Project

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2008

NOTA DE ACEPTACIÓN

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FIRMA DEL PRESIDENTE JURADO

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JURADO

Medellín, 13th of May 2008

GRATEFULNESS

During the twelve months in the development of this project, many people were helping to make it possible. Thanks to:

Mr. Phillip Soyza
MR Print SDN BHD
Carlos Alberto Montaña Hoyos
Victor Manuel Cock Lopera
Product Design Engineering Department of EAFIT University.
Family and Friends

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GLOSSARY

CORK: Is a flexible material as a hard sponge and its function is to eject the paper from the mold. When the machine presses the mold against the cutting plate to cut the paper, the corks are compressed, but after the cut is done, they recover the initial shape ejecting the paper.

CREASING RULES: Are to give an engrave line for folding in products as boxes, folders, card, etc.

CUTTING KNIVES: Are the ones to cut the desirable shape on the paper.

DIE CUTTING: The die cutting process involves the use of metal dies to give paper or substrate products specific shapes or designs that cannot be accomplished by a straight cut on a web press or a guillotine cutter.

DIE: Pattern on a mold to cut or emboss a specified figure on paper.

EMBOSSING: Process that involves to mold or carve in relief on a paper surface different shapes and figures.

HANDCRAFTED WORK: Activity that does not have an industrial connotation. It is not suitable for high work levels.

PDS: Product Design Specifications.

PRELIMINARY OR INITIAL PROTOTYPE: A prototype that does not have the final materials and dimensions, but can prove the functional working principle of the product.

PRESS BOARD: It is a surface located at the bottom between the cutting plate and the paper to protect and prevent the cutting knives of the die from damage or deformation, when the cutting is being done.

SECURITY FACTOR: The Security Factor is a value used in engineering calculations to guarantee the performance of the element being tested. The result of the calculus is multiplied by this value to assure that it is being considered in higher risk level.

SUMMARY

MR. PRINT SDN BHD is a graphic design, printing and delivering company located in Kuala Lumpur, Malaysia since 1993.

This project is the result of an analysis and study made internally in MR PRINT SDN BHD, to identify the activities that present problems in terms of performance, time and cost. The idea is to solve one of the biggest needs in one of the most important processes in the company: the die cutting and embossing activities. The project includes the design and development of a manual machine (using human power) to do, in a faster and easier way, all the paper die cutting and embossing activities for all the client's requests below 200 units or trial and tests runs.

The proposal is a product able to use the large inventory of embossing and die cutting molds available in the company (around 500 units); these are the same molds used in the automatic machines (when the quantity is over 200 units, high volumes).

The requirement to use these molds came from the company and it is justified in the fact that the cost of producing one mold is considered cheap (approximately RM100 = US$25), so it is easier to get as many molds as they are going to be needed in the future depending on the work and the reference to be cut.

The development of this project is based on all the conditions and requirements given by the company. The product specifications are the result of this process combined with the result of a research and analysis made to the market, the activities and the operators involved at the company.

INTRODUCTION

Context:

MR PRINT SDN BHD is probably the only printer in the area with a full-scale, in-house Creative Studio which is on par with even the best below-the-line advertising agencies in town. Their creative team has the ability to deliver quality designs and Finished Artwork. [1]MR Print operates on a flexible system that allows it to adapt fastly to changes in the industry. This dedication and flexibility allows MR Print to maintain a crucial lead over its competitors.

In a move that has greatly enhanced its capacity, MR Print's current premises are part of its strategic initiative to ensure long-term growth. Cutting-edge equipment and machinery are in place to meet dynamic market demands for excellent service and products. The operations of the company are in local and international levels with important customers in Australia and the United Kingdom.

The Project:

This final report is organized according to the methodology used during the process of development of this project. In the first stage all the issues concerned to the preliminary phase of research and analysis: the market, the company and the operators, are developed. The next stage is dedicated to present the results, the conceptual design, generation of alternatives and ideas, selection and evaluation, detailed design, 3D modelation and drawings, and a preliminary prototyping (not of the definitive product, but a prototype to test and prove the efficiency and correctly performance of the functionality of the product mechanisms).

[1] MR PRINT company profile.

1. JUSTIFICATION

Normally when we talk about a graphic printing company, the client goes with the design-art work ready to the final printing process.

MR PRINT SDN BHD is not only a printing company, it is as well in charge of the design process to give an excellent final result, than beyond the quality, it is supported in a suitable interpretation of the needs expressed by the client, always looking forward for high satisfaction levels. Due to this competitive advantage, the company is covering national and international markets, with strong clients in overseas countries such as Australia and the United Kingdom.

In MR PRINT there is never a ''NO'' as an answer to a client. This means that in some situations there is not enough infrastructure to satisfy some of the needs in a suitable way. Punctuality is always one the major values of the company.

To maintain the high availability for the clients, the company needs an appropriate technology to manage volumes when low demand levels are required.

It is a challenge to offer this kind of services which are not only providing a good final product to the client, but they are as well, a way to improve the efficiency levels, from the process and the commercial relations perspective, saving time and cost and improving the comfort and ergonomic conditions for the operators.

For these reasons, the design and fabrication of a tool to facilitate the die cutting and embossing activities is justified. This tool must be designed for requests below 200 units and all the trial and test runs, replacing the handcrafted way and it must have a low cost of operation. Economy and efficiency for small quantity work is the goal.

2. PROBLEM DEFINITION

The products in MR PRINT are: company reports, brochures, catalogues, books, labels, cards, invitations, advertising material, souvenirs; as it is shown in the Figure 1:

Figure 1: Examples of products

Own Elaboration

The major problem detected in MR PRINT is basically that in case of low quantity and trial run requests, is not profitable to use the automatic die cutting and embossing machines, because the number of units is not covering the set up, operation cost and time of those machines.

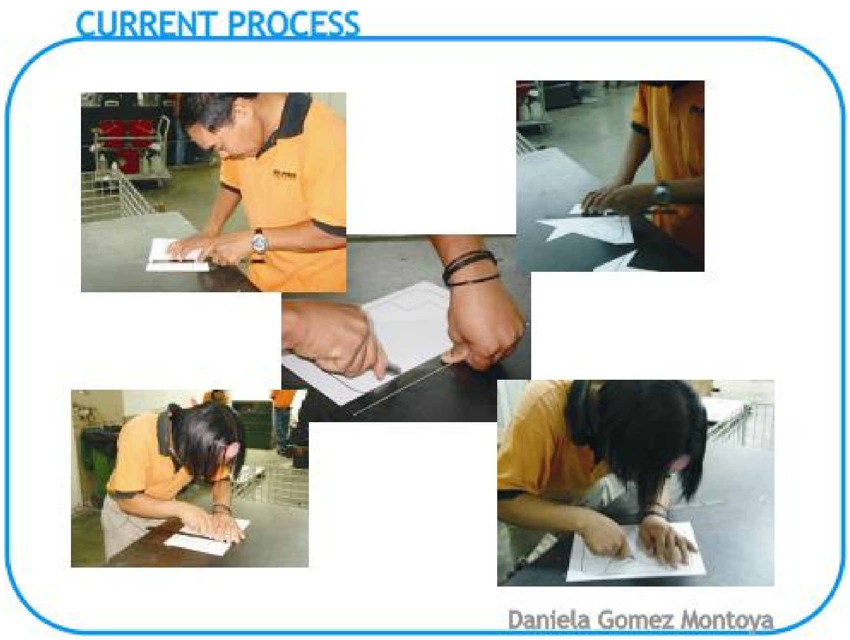
Currently, these processes are being done in a ''manual'' way, which means with ruler and blade, being low efficiency in time, cost and quality; forcing the operators to repetitive movements and wrong body-positions, which are not recommended from the ergonomic perspective.

It is a very important part of the problem that the company has many references (more than 500) and designs that are not standardized.

It is not easy to use the die cutting and embossing manual machines available in the market, because they are limited to a specific design of a mold or blade, with no option or possibility for the molds already available at the company.

In MR PRINT there is a high error level caused by the hand-made work which is translated in wasted paper and low quality.

Figure 2: Current process in MR PRINT for low quantity requests (below 200 units)



Own Elaboration

3. OBJECTIVES

3.1 GENERAL OBJECTIVE

To design a manual tool to facilitate the entire die cutting and embossing activities of graphic material (paper), for low quantity and trial – test run requests (below 200 units). This machine should be easy and fast to set up and to operate, with options of variety and versatility for regular and irregular shapes. The whole project will be done using a design research methodology that will consider conceptual elements, shape, functional and mechanical, ergonomic and production aspects.

3.2 SPECIFIC OBJECTIVES

3.2.1 To determine the Company's needs, through the study of graphic typologies required by the clients and to analyze the time and processes involved, in order to develop possible ideas and alternatives for the production of low quantity requests.

3.2.2 To analyze the existing products, through a partial market study specialized in related products, to evaluate options and designs available and to establish restrictions and advantages.

3.2.3 To formalize the idea, based in a conceptual design methodology, Brief and PDS, functional analysis, etc; in order to clarify and translate the client and operator's needs and to establish the complete engineering requirements for the product.

3.2.4 To develop the mechanic design of the product, according to a methodology based on the book *"Engineering Design"* from PAHL y BEITZ and the operator's analysis, their activities and the application of the PDS, in order to guarantee a good performance and to satisfy the functional and ergonomic requirements.

3.2.5 To elaborate the formal design of the product for die cutting and embossing, through a methodology considering the principles and knowledge acquired in the emphasis line of design and form, combined with aesthetic and semantic elements, to facilitate the tasks in the company in terms of use, efficiency and the effectiveness between user-product.

3.2.6 To produce a preliminary or initial prototype, not the definitive product, using the facilities of the University and the student's, in order to test the functional performance of the product (working principle for Die Cutting and Embossing) and do the user and performance test for further refinement of the tool.

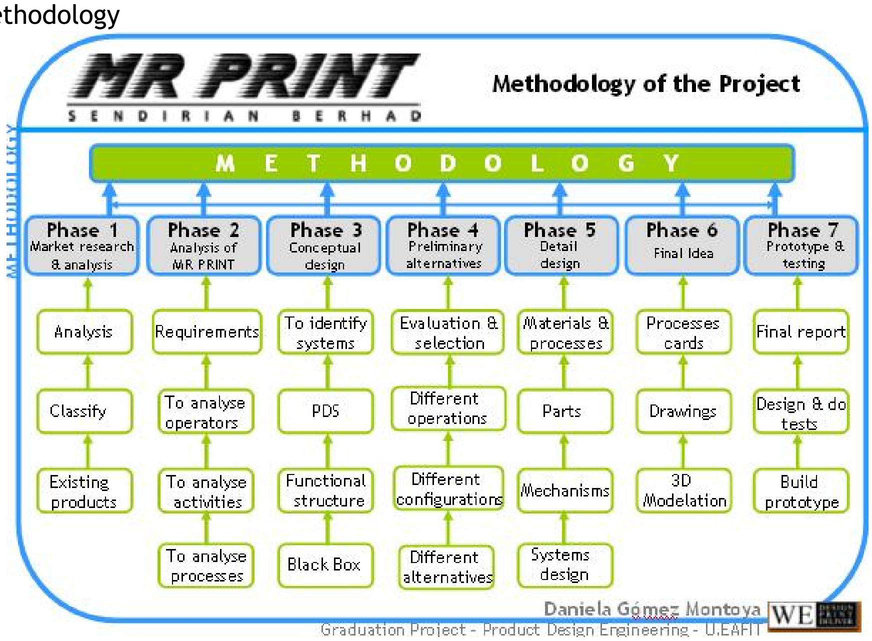
4. METHODOLOGY

The Final Methodology that is going to be used for the development of the graduation project is a mix of diverse methodologies and processes, taking different value elements coming from:

- All the semesters studying Product Design Engineering in assignments as: PROJECTS 1 TO 8, MODELS AND PROTOTYPES, DESIGN WORKSHOP, DESIGN STRATEGIES, CONCEPTUAL & METHODICAL DESIGN, PRODUCT DESIGN SPECIFICATIONS, FORMAL DESIGN THEORY, ETC.
- PAHL & BEITZ Methodology. "Engineering Design, a Systematic approach" Springer, Third edition.
- ULRICH & EPPINGER Methodology. "Product Design and Development". McGrawHill. 2004
- Activities and elements suggested by the company: MR PRINT SDN BHD
- Activities and elements suggested by the Project assessors: **CARLOS ALBERTO MONTAÑA HOYOS** and **VICTOR MANUEL COCK LOPERA.**

This project does not make an emphasis in the identification of a problem or need within a company, as the needs and problems were previously identified by MR PRINT SDN BHD. However, the validity of the problem was analysed before starting the project.

Figure 3: Methodology



Own Elaboration

The **Figure 3** shows a brief of the following phase-by-phase methodology used during this project:

4.1 PHASE 1:Research & analysis of the market

During this phase, the objective is to seek and find the entire range of die cutting and embossing machines available in the market (existing products), analyse and classify them in categories, looking for advantages and disadvantages.

It is very important to understand how they work and the elements involved, that make them unsuitable for the currently needs of MR PRINT.

4.2 PHASE 2: Analysis of the company MR PRINT SDN BHD

During this period of time, the idea is to analyse the process of die cutting and embossing inside the company. How are the activities being done? Which are the problems and positive aspects identified? How is the way the operators are doing the work? It is important to analyse the work place.

In this phase, most of the conditions and requirements of the company for the project are going to be determined.

4.3 PHASE 3: Conceptual design

Once the two first stages of the methodology are almost completed and all the preliminary specifications and requirements are defined, the conceptual development of the ideas can be started.

Most of the tasks to develop in this phase are taken from the methodology of PAHL & BEITZ (Engineering Design) and ULRICH & EPPINGER (Product Design and Development) and from the methodologies used by the Product Design Engineering Department of EAFIT University.

4.4 PHASE 4: Preliminary creation of ideas & possibilities

During this phase, the process of generation of design alternatives is started based on the developments and analysis of the previous phases.

As we are talking about a manual machine that involves the design and solution of many sub–systems to complete the whole product, the objective here is to have a general conception (not in detail) of as many options as possible, including:

- Different configurations
- Different options of operation

All the sketches and drawings generated should have an explanation of the idea. To enhance creativity, It is important to compile all the ideas, even if they seem not so feasible, because these could be the beginning of a good solution.

From all these general options, without thinking in the detail of each one, the best ideas are chosen to be developed in detail in the next phase.

The last step during this phase is the evaluation and selection of the alternatives in order to chose those which better accommodate to the final solution for further refinement and development.

4.5 PHASE 5: Detail design

Once the ideas are evaluated and discussed with the company and the project assessors, the next step is to start with the design of the details of the best alternatives to land all the options according to real conditions. It is important to research about available mechanisms and solutions, in order to have the entire panorama to better solve the problem.

All the elements that should be defined here are, as follows:

- Possible options for each mechanism for all the systems.
- Mechanisms with components and parts defined.
- Design for manufacturing, assembly and maintenance.
- To define each part geometrically.
- To select the materials.
- To define the process of the prototype making construction.

All the steps during this phase are in accordance with the requirements in the PDS.

4.6 PHASE 6: Final idea: Modelation and technical drawings

This phase should define the definitive alternative with the final details in order to develop a 3D modelation and all the technical drawings, before the making of the prototype begins.

4.7 PHASE 7: Prototype, testing & corrections

The objective here is to build an initial prototype and to design and develop all the tests to ensure the good performance of the prototype and make all the corrections if that is the case.

5. THEORETICAL BACKGROUND AND CONCEPTUAL BASIS

5.1 HISTORICAL FACTS

5.1.1 History of the printing industry. "In 1440, a German called Johannes Gutenberg invented a printing press process that, with refinements and increased mechanization, remained the principal means of printing until the late 20th century. The inventor's method of printing from movable type, including the use of metal molds and alloys, a special press, and oil-based inks, allowed for the first time the mass production of printed books"(GREAT@2007).

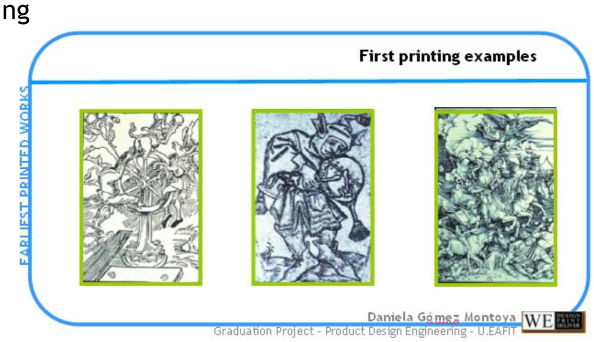
Gutenberg gave birth in 1436 to *"an art"* that played and important part on the industrial revolution and today is one of the most advanced and technological developments. "He was German, his press was wooden, and the most important aspect of his invention was that it was the first form of printing to use movable type" (GREAT@2007).

It is important to make clear that printing is not an invention of only one brain. It is an aggregation of multiple theories and technologies from before Gutenberg.

Even today, the printing technology and industry are changing very fast, with facilities and results not expected before. Now days it is possible to do amazing things. One of the best results in the industry is coming from the digital image with the development of different kind of software, making possible real-printed pictures, touched up works, effects, editions, etc.

This is combined with all the different kind of papers invented, in many textures and qualities to do many of the things that the human being can think.
The **Figure 4** shows some of the examples of the earliest printing time (1436).

Figure 4: Earliest Printing



Wikipedia

5.1.2 Industrial Automation. In the industrial automation control systems are used to lead industrial machinery and all the processes trying to replace human power or operators. It is providing assistance to human operators with the physical requirements of work. "Automation greatly reduces the need for human sensory and mental requirements as well" (WIKIPEDIA-AUTOMATION@2007).

"Automation plays an increasingly important role in the global economy and in daily experience. Engineers strive to combine automated devices with mathematical and organizational tools to create complex systems for a rapidly expanding range of applications and human activities" (WIKIPEDIA-AUTOMATION@2007).

Automation has helped to increase efficiency, saving time and cost, in the industry. The interesting for innovation came since the XVIII century. There are many reasons for it: high demand of products, saving costs in human force and an effort to cover more markets. Currently, for manufacturing companies, the purpose of automation has shifted from increasing productivity and reducing costs, to broader issues, such as increasing quality and flexibility in the manufacturing process.

Combined with the automation of the industry, there are more issues involved: for any kind of equipment or machinery, it is always necessary to have skilled force to provide repairs and maintenance, as so for the operation activities.

Nowadays automation means quality, flexibility and convertibility of the processes at the industry. "Manufacturers are increasingly demanding the ability to switch from one product reference to another one in a fast and easy way, without having to completely rebuild the production lines" (WIKIPEDIA-AUTOMATION@2007).

5.1.3 The Company: MR PRINT SDN BHD[2]

[2] Information from the Company and Managing director Mr. Philip Soyza

MR. Print Sdn Bhd is probably the only printer with a full-scale in-house Creative Studio, which is on par with even the best below-the-line advertising agencies in town. Its creative team has the ability to deliver quality designs and Finished Artwork, at very competitive prices.

Figure 5: MR PRINT

MR. Print SDN BHD

At MR Print, quality means three things. First, quality service - it continuously strives to exceed their customer's expectations. Second, quality people - it nurtures a culture that thrives on quality and drives everything they do. Third, quality operations - it minimizes waste and maximizes value for their customers, thus boosting investor value.

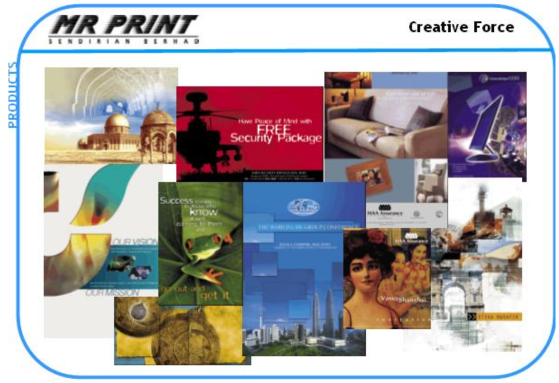
MR Print Sdn Bhd, a member of SERISAR INDUSTRIES BERHAD, Group of Companies was incorporated in 1987.

Today it is the preferred printer for many reputable organizations. Maintaining a results-orientated philosophy, MR Print operates on a flexible system that allows it to adapt faster to changes in the industry. This dedication and flexibility allows MR Print to maintain a crucial lead over its competitors.

In a move that has greatly enhanced its capacity, MR Print's current premises are part of its strategic initiative to ensure long-term growth. Cutting-edge equipment and machinery are in place to meet dynamic market demands for excellent service and products.

As part of its move to provide value-added service for its clients, MR Print's Pre-Press Services include creative and design work. Always believing that the customers deserve only the best, MR Print's Creative Department, offers top-quality pre-press services. Customers are now able to see their ideas conceptualized and realized by experts, all under one roof. The creative department comprises a team of talented artists lead by a highly experienced Art Director.

Figure 6: MR PRINT Creative Force



MR. Print SDN BHD

Currently MR PRINT is producing a wide variety of references for different kind of products in a local and international levels. Some examples are: labels, folders, envelopes, boxes, invitations, business cards, souvenirs, company reports, catalogues, flyers, etc.

Figure 7: MR PRINT finished products

MR. Print SDN BHD

Figure 8: MR PRINT finished products 2

MR. Print SDN BHD

5.3 TECHNOLOGICAL FACTS

5.2.1 Die cutting process. The die cutting process involves the use of metal dies[3] to give paper or substrate products specific shapes or designs that cannot be accomplished by a straight cut on a web press or a guillotine cutter. By using knife-edge cutting blades formed into a pattern or die, a machine presses the die into the material to produce the desired shape. Almost any shape can be created and applied to a diverse array of raw materials. Labels, envelopes, folders, cardboards, and documents are only a few of the many printed products that can be die cut.

Web presses often have a rotary die unit that is utilized for die cutting paper and label stocks. Although there are limitations on the types of dies and paper selections that can be provided, rotary die cutting serves as an effective method for longer run quantities of printed materials requiring some type of die cut area. Single sheet products require the use of a flat bed die and a flat bed cutting press to die cut the shape into the paper stock. The speed of this process is slower than a web press, but it does provide die cutting capabilities to a wider variety of paper stocks and printed products"(INTERNATIONAL@2007).

Figure 9: Die Cutting Examples

International Paper Knowledge Centre

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[3] Pattern to give an specific shape to the paper.

In high-volume die cutting operations, fully automatic machines are used. The material to be cut is automatically fed into the press and located in the proper position. The steel die is pressed through the material and the pressure is released. The cut piece is removed along with any scrap material, and the next piece is indexed to repeat the process. (Flexographic, 1980, 26)

There are different kinds of dies used during the die cutting process (it depends of the kind of machine) (Flexographic, 1980, 26):

- **Mallet Handle die:** This was the first kind of die created. They were originally fashioned by a blacksmith to the desired configuration of the product to be produced. After the cutting edges were hand-sharpened and heat treated, a handle was attached to the back of the die which could be struck with a mallet to force the die through the material to be cut.

- **The clicker die:** As the Mallet handle die, the Clicker die's blade is bent or fabricated to conform to the design configuration. No external support is required to prevent the cutting knives from bending.

- **The steel rule die:** This is probably the most commonly used with most of the web and sheet fed equipment. Here the cutting knives are flexible and relatively thin. They must therefore be imbedded in or otherwise supported by a thicker, solid material such as playwood.

- **The male-female die:** It is made of two distinct (upper and lower) sections. Each section is made of hardened steel blocks which must be mated with extreme accuracy in order to accomplish the scissor type cutting action inherent to this form of die cutting. It is most useful in the production of tags and labels.

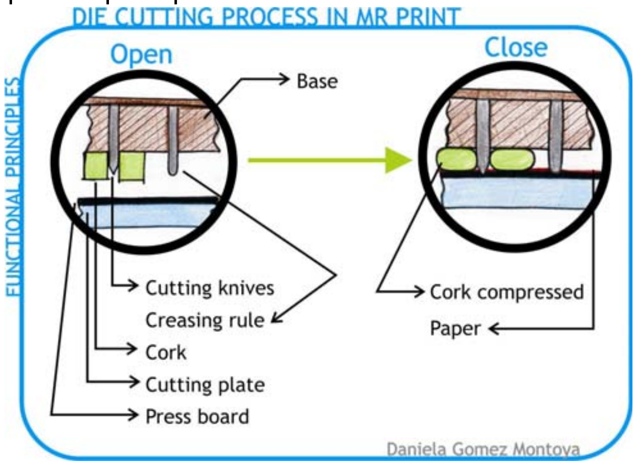
- **Rotary dies:** Because of their curve configuration, they are more difficult and time consuming to build and therefore more expensive. They are normally used on a web press. The die is a fixed to a metal roller.

The function of any die cutter is to operate the die and to control the flow of material as it enters and exits from the die area.

The process at MR PRINT

The following figure shows graphically how the die cutting process principle works at the company using, as it was explained before, flat bed dies.

Figure 10: Die Cutting process principle at MR PRINT



Own Elaboration

The cutting knives are the ones to cut the desirable shape on the paper and the creasing rules are to give an engrave line for folding in products as boxes, folders, cards. The cork is a flexible material as a hard sponge like NEOPRENE[4] and its function is very important. When the machine presses the mold against the cutting plate to cut the paper, the corks are compressed, but after the cut is done, they recover the initial shape and eject the paper from the mold.

The press board is made of a flexible material as "Polystyrene hardness 80 shore A"[5]. It is a surface located at the bottom between the cutting plate and the paper to protect and prevent the cutting knives of the die from damage or deformation, when the cutting is being done.

5.2.2 Embossing Process (INTERNATIONAL@2007) (WIKIPEDIA-Embossing@2007). Often used in combination with foil stamping, embossing is a process that applies pressure to the backside of a material to alter the surface, giving it a three dimensional or raised effect. This is achieved by using a metal die (female) usually made of brass and a counter die (male) that fit together and actually squeeze the fibers of the substrate. This pressure and a combination of heat actually "irons" while raising the level of the image higher than the substrate to make it smooth. In printing this is accomplished on a letterpress. Generally, embossing is the process most often employed to attract attention or convey a high quality textural contrast in relation to the surrounding area of the stock. A thorough understanding of the process will allow for a more successful result. An embossed image is shown below.

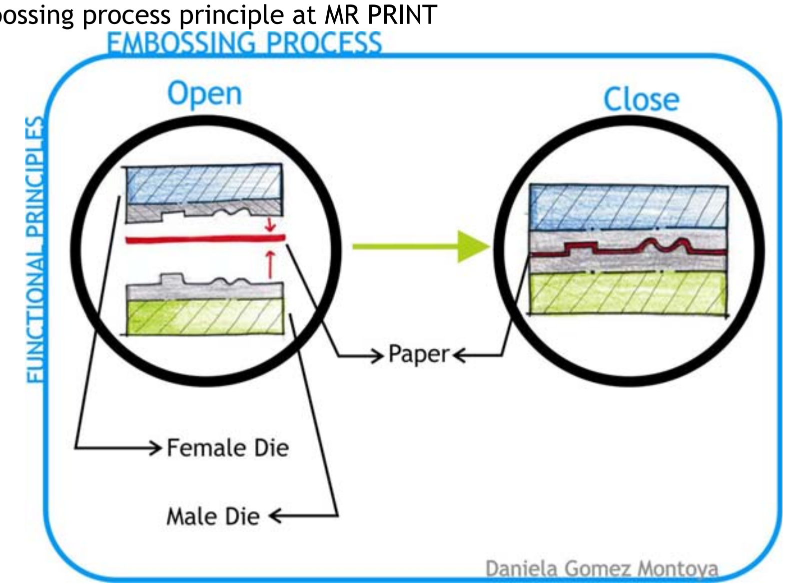
[4] Neoprene is an elastomeric material developed by DUPONT.
[5] LONDONO, Nelson. Lecturer of UdeA University.

Figure 11: Embossing Examples

International Paper Knowledge Centre

Embossing differs from other relief design processes, such as repoussé, chasing, carving, and leather tooling, in being machine wrought.

Figure 12: Embossing process principle at MR PRINT



Own Elaboration

5.2.3 Current technology and machines

❖ Manual Machines

The current and available manual machines for die cutting and embossing are not suitable for industrial use which means heavy work (8 hours a day).

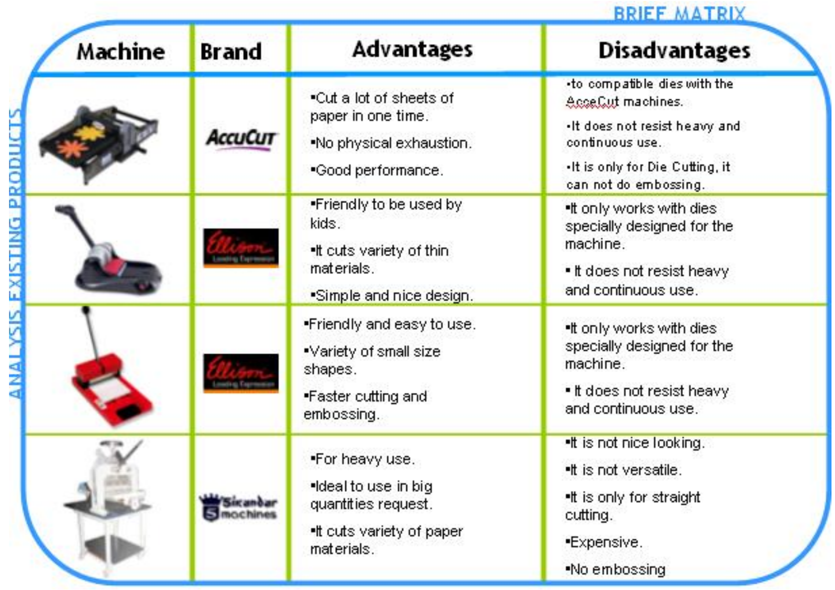
On the previous research made to analyze the market, the common factor was to find some different manual machines for a very handicraft use. All these machines, without exception, can be used only with specially designed dies produced by the brand company. It means that, in the case of MR PRINT, the machine is not appropriate, thinking in the inventory of dies that must be used at all times. Some of the examples found are in the **Figure 13**:

Figure 13: Manual Machines Examples

Ellison, Accucut, Sikandar

The **Figure 14** shows a Brief of the analysis made for the manual existing products. The Complete Analysis can be found at the **Annex No. 1** at the end of this report. As a conclusion, the ACCUCUT machine offers a good solution in performance that can be taken as a reference during the development of the product.

Figure 14: Brief Matrix for the Existing Products Analysis.



BRIEF MATRIX

ANALYSIS EXISTING PRODUCTS

Machine	Brand	Advantages	Disadvantages
	AccuCut	•Cut a lot of sheets of paper in one time. •No physical exhaustion. •Good performance.	•to compatible dies with the AcceCut machines. •It does not resist heavy and continuous use. •It is only for Die Cutting, it can not do embossing.
	Ellison	•Friendly to be used by kids. •It cuts variety of thin materials. •Simple and nice design.	•It only works with dies specially designed for the machine. • It does not resist heavy and continuous use.
	Ellison	•Friendly and easy to use. •Variety of small size shapes. •Faster cutting and embossing.	•It only works with dies specially designed for the machine. • It does not resist heavy and continuous use.
	Sicanbar machines	•For heavy use. •Ideal to use in big quantities request. •It cuts variety of paper materials.	•It is not nice looking. •It is not versatile. •It is only for straight cutting. •Expensive. •No embossing

Own Elaboration

❖ Automatic Machines

Since the printing process was invented, science and technology have shown unbelievable progresses, as well as in all different areas of industry. Now there are big and modern machines completely automated able to do heavy work in a very small period of time and in a faster way.

The automatic machines are also expensive and their use is only justified when a company needs to produce high quantity of units, creating an economy scale.

Normally the cost of operation of these machines is high (approximately UD$200 per hour), and so is the time that an operator needs to set it up for each reference, due to that the company does not want to use those machines for small works. The production of units per machine should surpass the equilibrium point, covering the operational costs and giving profit to the company, otherwise, the use of these machines is not suitable and it can bring high loss of money. Some examples of automatic machines are in the **Figure 15:**

Figure 15: Automatic Machines Examples

Crossland

5.2.4 Opportunity and market matrix

Figure 16: Opportunity Market Matrix

Own Elaboration

The **Figure 16** shows a summary of the existing and available products analysis made starting the process. The two axes are dividing the matrix horizontally between Industrial and Handicraft use and vertically between Manual and Automatic machines. Around that area the machines found were located. Notice that there are almost not available machines for an industrial use working manually.

That is our market opportunity and the major need of the company: a totally manual machine, able to do industrial work using the available dies and molds in MR PRINT for the automatic machines, but in this case only when the request of units is below 200 units.

5.3 COMPANY CONTEXT

5.3.1 Company Clients[6]. The flexibility of MR PRINT SDN BHD has located it as one of the most important companies in the graphic industry. That flexibility makes possible that any type of work requested by the client can be done. No matter the shape, complexity level or quantity, everything is possible. From big industries and companies of all sectors to small companies, universities, etc; at local and international levels, these are some of the clients of MR PRINT, **Figure 17:**

Figure 17: Automatic Machines Examples

Own Elaboration, MR. PRINT

5.3.2 Available machines at the Company

To complete its job successfully, MR PRINT has Automatic machines imported. As an example, the **Figure 18** shows one of them: **Creasing and Cutting Machine PYQ1300C/1480C.** YAWA a producer from China:

[6] Info from MR PRINT SDN BHD – Mr Philip Soyza, Managing Director

Figure 18: Semi - Automatic Die Cutting Machine of MR PRINT

YAWA

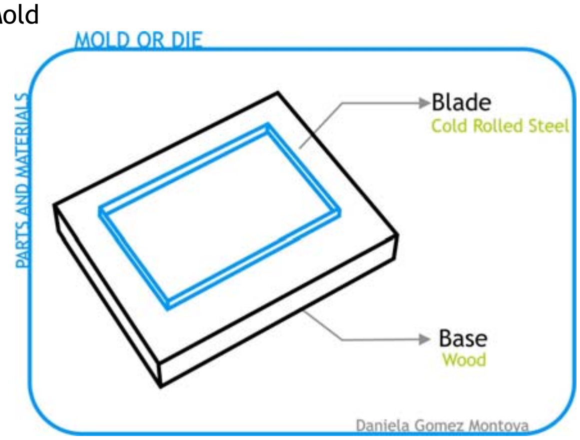
The setting up activities of this machine is taking a lot of time due to the manual feeding that forces the operators to make a lot of trials, before getting an exact and excellent die cutting or embossing. Its operation cost is expensive for low quantity works (below 200 units).

5.3.3 Available dies and molds at the company.

There are different kinds of dies and molds available in the company for die cutting and embossing. The whole report about company's molds and dies is in the **Annex No.2** at the end of this document.

The mold is made of a wood base with a blade or ruler made of Cold Rolled Steel. This kind of steel has high hardness, high wear resistance, high compression resistance, impact resistance. (ACEROS@2007)

Figure 19: Die Cutting Mold



Own Elaboration

The result of this project should be a manual machine able to use this molds with a maximum mold area of 400mm x 500mm[7]. The machine will be use for low requested works of units (below 200 units per reference).

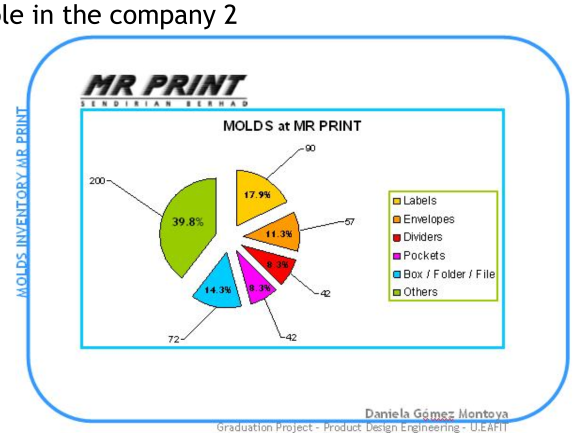
Figure 20: Automatic Machines Examples

Own Elaboration

Figure 21: Molds available in the company 1

Own Elaboration

Figure 22: Molds available in the company 2



Own Elaboration

[7] Company Request.

5.3.4 The raw material: PAPER

- **Description** (WIKIPEDIA-Paper@2007)

Paper is thin material for many uses like writing upon, printing upon or packaging. It is produced by the amalgamation of fibers, typically vegetable fibers composed of cellulose, which are subsequently held together by hydrogen bonding. While the fibers are usually natural in origin, a wide variety of synthetic fibers, such as polypropylene and polyethylene, may be incorporated into paper as a way of imparting desirable physical properties. The most common source of these kinds of fibers is wood pulp from pulpwood trees. Vegetable fiber materials such as cotton, hemp, linen, and rice are also used.

- **Finishing** (WIKIPEDIA-Paper@2007)

The paper may then undergo sizing to alter its physical properties for use in various applications. Paper at this point is *uncoated*. *Coated* paper has a thin layer of material such as china clay applied to one or both sides in order to create a surface more suitable for high-resolution halftone screens. Coated or uncoated papers may have their surfaces polished by calendering. Coated papers are divided into matt, semi-matt or silk, and gloss. Gloss papers give the highest optical density in the printed image. The paper is then fed onto reels if it is to be used on web printing presses, or cut into sheets for other printing processes or other purposes. The fibers in the paper basically run in the machine direction. Sheets are usually cut "long-grain", i.e. with the grain parallel to the longer dimension of the sheet. All paper produced by Fourdrinier-type machines is wove paper, i.e. the wire mesh that transports the web leaves a pattern that has the same density along the paper grain and across the grain. Textured finishes, watermarks and wire patterns imitating hand-made *laid* paper can be created by the use of appropriate rollers in the later stages of the machine.

- **Types of paper used in the company**

The names of the references of the paper are not globally. Each paper company or producer in each country has a special way to name its papers depending on the type, quality, texture, uses, or other classification.

The **figure 23** presents the list of the most common references used in MR PRINT SDN BHD for die cutting and embossing activities.

The physic and chemic properties of the papers are very important in order to know their cutting resistance, humidity, elasticity, etc; elements that are used during the process for the engineering calculations of the machine and defined the product’s performance.

Figure 23: Types of papers used in MR PRINT

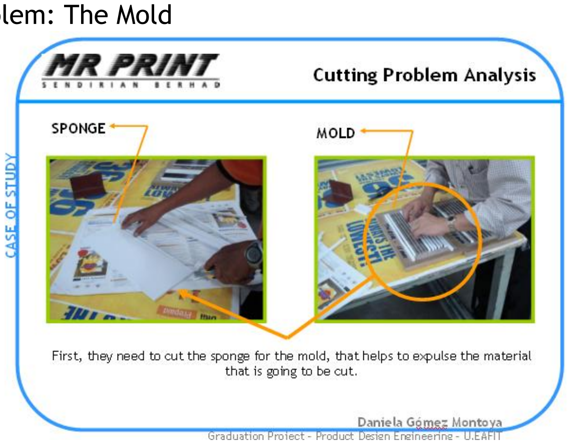
MR PRINT SDN BHD PAPER REFERENCES		
DESCRIPTION/Reference	**GSM**	**Characteristic**
Simili Paper	60	Similar to BOND Ordinary Paper
	70	
	80	
	100	
	120	
	140	
Aut Paper	85	Similar to PROPALCOTE. Bright finish.
	100	
	128	
	157	
Matt Aut Paper	100	Similar to PROPALMATE. Opaque finish.
	128	
	157	
Aut Card	180	
	190	
	230	
	260	
Aut Card (1 side coated)	230	1 Side bright, 1 side matt.

Own Elaboration

5.3.5 Cutting Problem Analysis (Case of study: Cutting an adhesive).

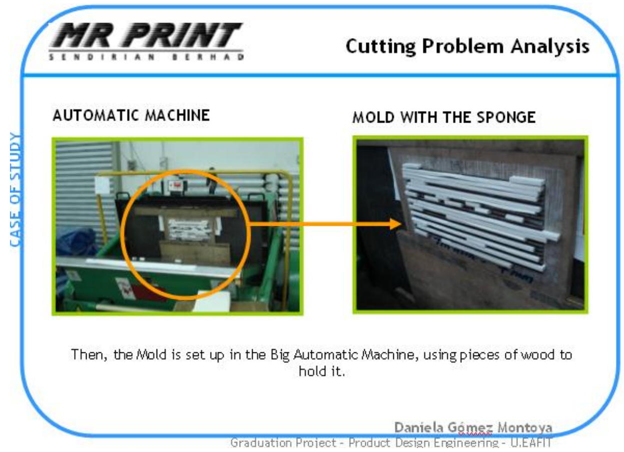
Recently, in MR PRINT, it has been a problem to die cut a new adhesive, imported from Japan. This Adhesive is very special for jobs as files with many pages inside. It is used to glue and keep them in place. The only machine they have for this work is a semi-automatic and it takes around 2 hours for the set up. On top of that the company is wasting time because the results are not so good and the cost implied is very high. Thinking of cutting by hand will take a lot of hours complete the work. The following sequence of figures will illustrate the problem:

Figure 24: Adhesive problem: The Mold



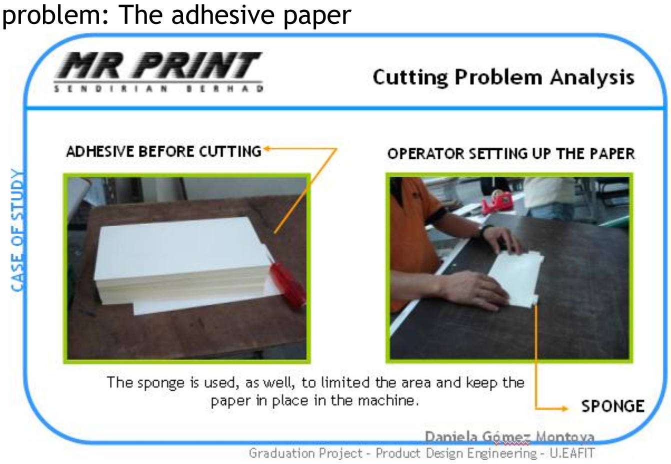
Own Elaboration

Figure 25: Adhesive problem: The Mold in the Machine



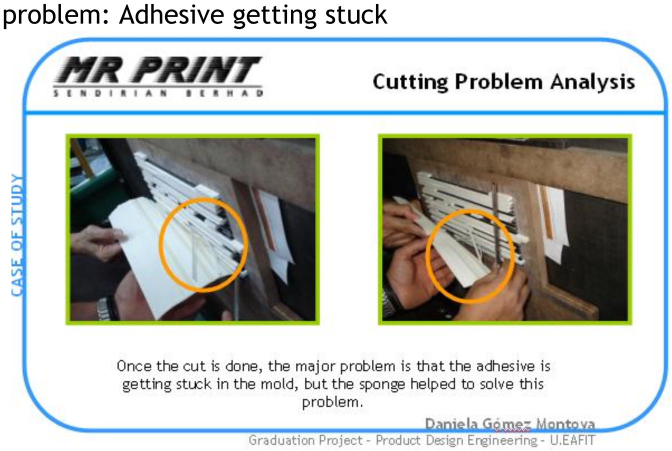
Own Elaboration

Figure 26: Adhesive problem: The adhesive paper



Own Elaboration

Figure 27: Adhesive problem: Adhesive getting stuck

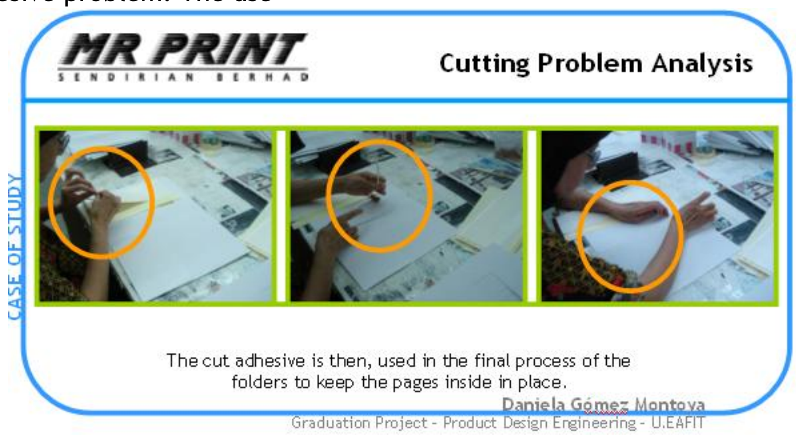


Own Elaboration

Figure 28: Adhesive problem: The result

Own Elaboration

Figure 29: Adhesive problem: The use



Own Elaboration

Figure 30: Adhesive problem: The Finished Product

Own Elaboration

5.3.6 Economic consequences for the company. Low quantity requests and trial or test runs are always difficult for the company, especially because most of the times it is complicated to get any profits using the automatic machines for cutting and embossing and always their operational cost is not being covered due to the small number of units produced.

Currently that kind of job is being done by hand. This process is not very efficient in terms of time and quality. It is more likely to have mistakes and errors and the waste of paper is high (5 kg per day).

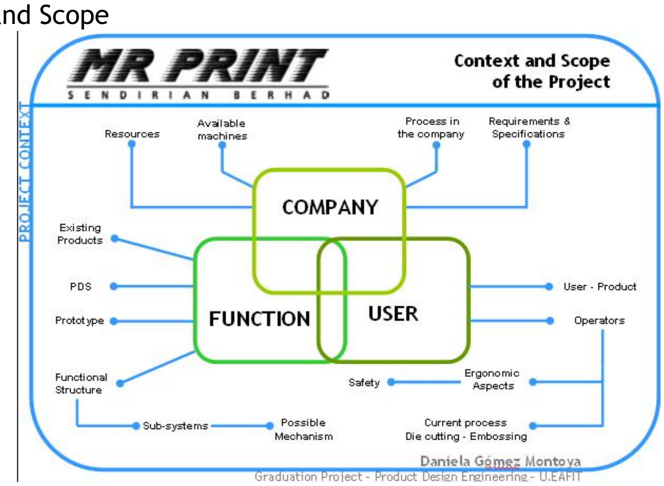
The investment in designing and manufacturing a manual machine specially to be used in MR PRINT, will give the opportunity to save not only cost, but also a lot of time and raw material wasted.

5.4 PROPOSAL

5.4.1 Context and Scope. The focus of the design project is to develop a manual machine for die cutting and embossing (using the same working principle) that seeks to improve the efficiency in the activities of MR PRINT SDN BHD (a graphic and printing company) for all low quantity requests of 200 units and below, by creating a friendly product which is easy and faster to set up and use, considering ergonomic, formal and functional elements; saving cost and time.

The design process will involve 3 main subject matters: the Company, the User and the Function. **Figure 31** depicts the mutually relationship between all three factors, defined within the project context. Thus, it is important to approach the research from these three starting points in order to ensure a coherent product design.

Figure 31: Context and Scope



Own Elaboration

5.4.2 Product Benefits. As it is explained before, the final product will be a manual machine that, using the available molds in MR PRINT SDN BHD, will be used in die cutting and embossing activities for low quantity requests, 200 units and below, and trial or tests runs. The benefits of the product are:

- **Saving time on the machine's set up activities**

Currently when it is required, MR PRINT is using an automatic machine for the die cutting and embossing activities. The time used to set up all the parameters in that machine for a specific work is high, compared with the quantity of units to produce when those ones are 200 or below. The operational cost is not covered by the sales of the final product.

The new machine, with a simpler mechanism and way of using it, will decrease those times in at least 70%, making easier and faster the setting up tasks, which will allow changing the production of low quantities from one reference to another in less time.

- **Saving operational and maintenance costs**

The simplicity of the manual die cutting and embossing machine, objective of this graduation project, will reduce the costs for operations and maintenance. MR PRINT will be able to accept any small quantity request. At the same its market can increase at least 5%, as the Company will be more flexible without any risk of increasing the cost.

- **Less errors**

The fact to use a machine, replacing hand work, can avoid human errors and mistakes, increasing the quality of the finished products and giving to the company the option to deliver in less time the final products.

- **Ergonomics issues**

A well designed machine, in ergonomic terms, can improve the health of the operators and prevent future injuries with suitable and correct positions, especially in all the topics related with the industrial work environment and safety.

- **Same working principle (roller compressionsystem)**

Both activities die cutting and embossing, will use the same working principle, but different die or mold. There will be two activities using just one machine.

NOTE: Unfortunately the company has very little information and knowledge about technical information and data needed for a successful design. For that reason a lot of research and test are required to do during then development of this project to get many relevant data as:

- Mechanical properties of the papers used (strength properties, elasticity, tearing.).

- Material and properties of the elastomeric material used on the mold to eject the paper once the cut is done.

- Material and mechanical properties of the rubber to support the impact and protect the steel blades at the cutting moment.

The company based most of its activities working in a “Trial and Error” way, by instinct; to solve the problems presented during the process.

6.1 PROJECT PROCESS AND RESULTS

6.1 CONCEPTUAL DESIGN (PAHL & BEITZ@2007)

The present report shows in a briefly but consistently way, how the process of conceptual design was followed during the project. This phase was highly based on the book *"ENGINEERING DESIGN"* of G. PAHL and W. BEITZ with their systematic approach for a product design process[8].

6.1.1 PDS – Product Design Specifications. The PDS is a very important tool that contains all the demands and wishes given by the company MR PRINT SDN BHD, during the requesting process of the product. These have been translated into engineering requirements to facilitate the development of the project and to clarify the objectives. To elaborate the PDS, the company MR PRINT SDN BHD gave just a few a basic specifications and conditions. These are highlighted in the file containing the PDS and shown as follows. The complete PDS is the result of the own investigation and research made during the first stage of the project, considering most of the elements explained in the document of MARIA CRISTINA HERNANDEZ[9] about Product Design Specifications.

ELEMENT	DEMAND / WISH	INTERPRETATION	D	W	REQUIREMENT			
					Unit	Value	Condition	Import
Performance	It cuts a big area	Mold biggest area.			Width x Length (cm)	40 x 50	Maximum.	5
	It works properly for low quantity requests.	Perfect die cutting and embossing for low quatity resquests.			Units	200	Maximum.	5
					# Sheets to be cut.	1 at the time.	Maximum.	5
Size and weight	It is not too heavy.	The assembled system should have a reasonable weight according with its purpose.			Kg	100	Maximum.	5
	It is not too big.				Width x Heigth x Length (cm)	80 x 80 x 50	Maximum.	5
		The maximum area of the die shouldn't be too big.			Width x Length (cm)	40 x 50	Maximum.	5

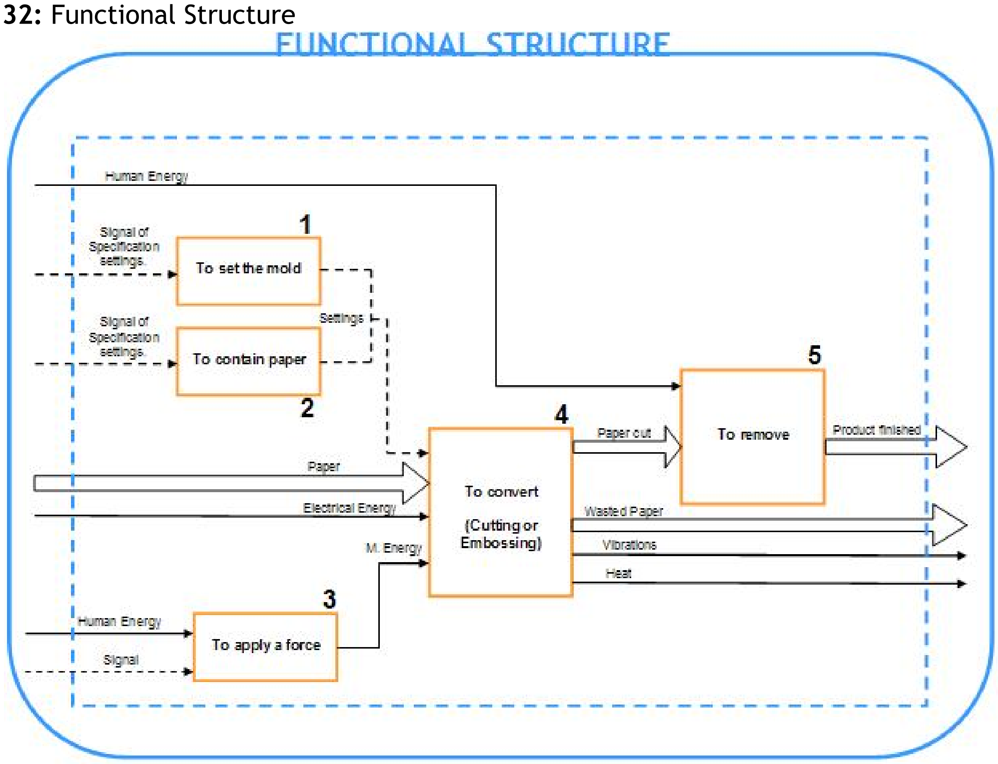
The complete PDS of the project is at the end of this report at the **Annex No3.**

6.1.2 Functional Structure. The Functional Structure represents the overall function and is useful, starting the design process, to identify functional relationships, the subfunctions and their *inputs* and *outputs* (flow of energy,

[8] Product Design and development process.
[9] Industrial Designer. Lecturer of the Product Design Engineering Department of EAFIT University; Medellin, Colombia.

substance and information). This is in order to open the path for variety of solutions and alternatives to be considered.
The following figure shows the functional structure for the Project. There are 5 major subfunctions to be considered in the design of the machine.

Figure 32: Functional Structure



Own Elaboration

❖ **FUNCTION 1: To set the mold.** Before starting the cutting or embossing process, the operator must do all the setting activities of the mold for the specific reference. The mold needs to be held in the correct position to ensure a perfect result. The flow for this subfunction is basically information. The operator will have the specifications to select and install the mold into the machine as an *Input* and the *Output* is the signal indicating that the machine has been set up.

❖ **FUNCTION 2: To contain the paper.** Depending of the kind of work the company needs to produce, the paper has to be selected. The machine will have a device that will hold the paper in the suitable position. The *Input* is signal or information, coming from the production order with the paper specification. The *Output* will be the signal indicating that the paper is ready and the cutting or embossing can start.

❖ **FUNCTION 3: To apply a force.** The person operating the machine needs to apply a force, as Human Energy (*Input*) to start the machine and make it work. Another *Input* is information or signal and Mechanic Energy is the *Output*.

❖ **FUNCTION 4: To convert (force into work).** This subfunction compiles both actions: die cutting and embossing, as they will use the same working principle. The only difference is the molding setting as they use different kinds of mold for both activities. This subfunction involves the way the cutting and embossing are going to be done. It includes the design of the mechanism for that specific purpose. The *Inputs* are: The signal indicating that the setting up has been done, the paper sheets (raw material), mechanic energy (result of the human energy) and as a possibility it could involve electrical energy. The *outputs* are mainly wasted paper, energy as vibrations and heat and cut paper.

❖ **FUNCTION 5: To remove paper.** This subfunction is very simple, involving only the action of removing the paper as finished product from the machine, once the process has been done. The *Input* is the cut paper and the *Output* is the "finished product".

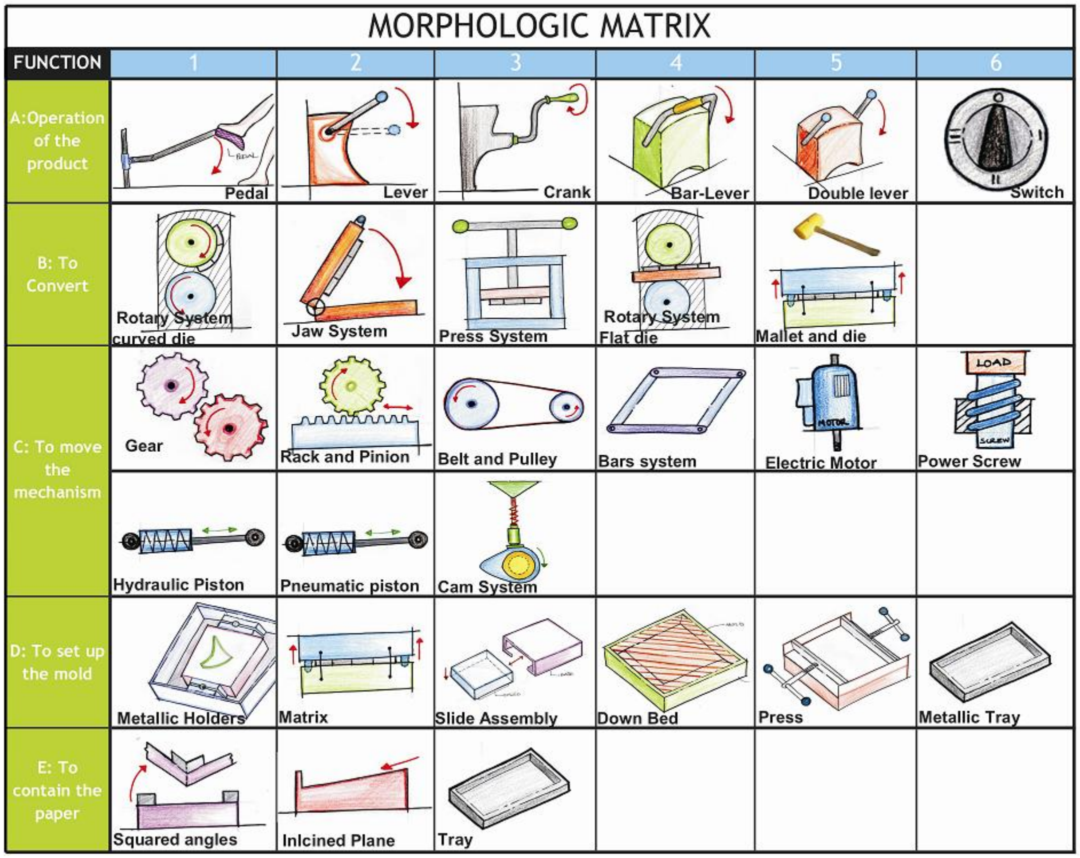
6.1.3 Working Principles and Morphologic Matrix. Working principles need to be found for the various subfunctions, and these principles must eventually be combined into a working structure. The materialization of the working structure will lead to the final solution.

Some of the methods used in the search for working principles are literature searches, methods for analyzing natural and known technical systems, intuition-based methods, catalogues, websites, etc.

The Morphologic Matrix is a search for possible solutions for the project and a way to make a systematic analysis about how the product can be assumed. The matrix shows in rows, different solutions and working principles for each subfunction represented on the structural function. This allows getting different functional combinations for the process of generating product (functional) alternatives. The different systems considered at the matrix are explained in further detail in the **Annex No.4.**

There are six different combinations chosen and can be used to start developing of the ideas.

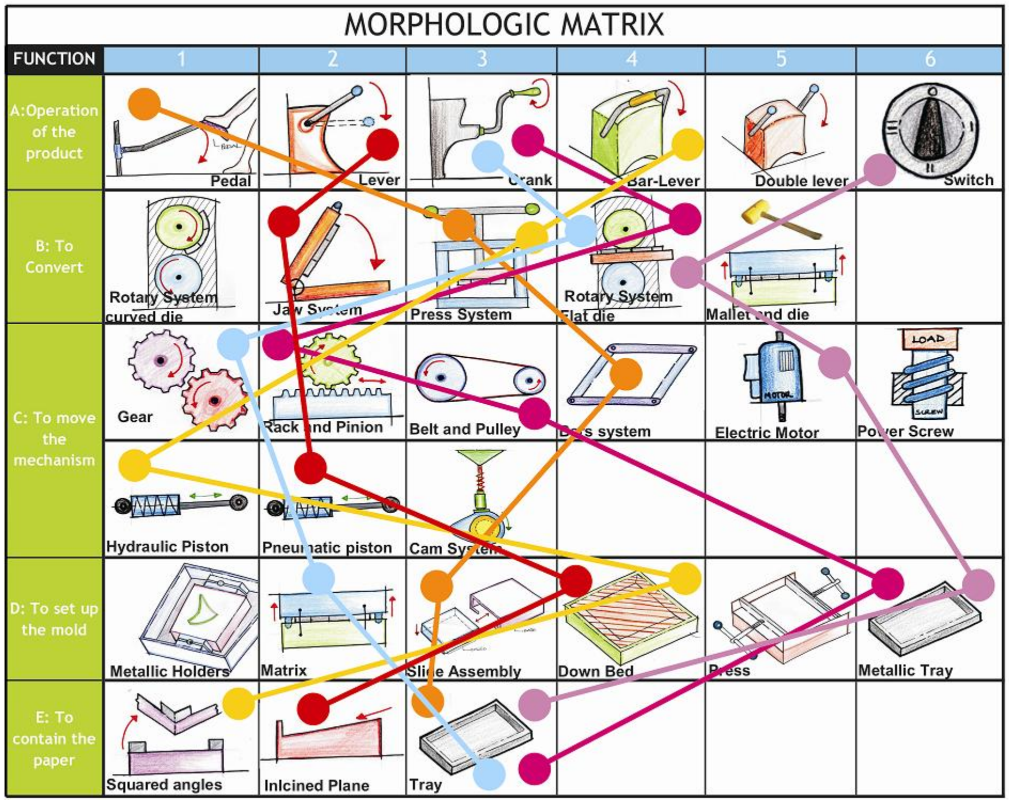
Figure 33: Morphologic Matrix



Own Elaboration

6.1.4 Working Structures: Possible Combinations. To fulfill the overall function, it is then necessary to generate overall solutions by combining the working principles into a working structure, that is, a system synthesis. The basis of such a combination is the established function structure, which reflects logically and physically possible or useful associations of the subfunctions. The working structures are generally not very concrete and the properties are only known qualitatively.

Figure 34: Morphologic Matrix – Working structures



Own Elaboration

WORKING STRUCTURE 1
Pedal + Press system + Bars system + Slide assembly + Tray

WORKING STRUCTURE 2
Lever + Jaw system + Pneumatic piston + Down bed + Inclined bed

WORKING STRUCTURE 3
Bar lever + Press system + Hydraulic piston + Down bed + Squared angles

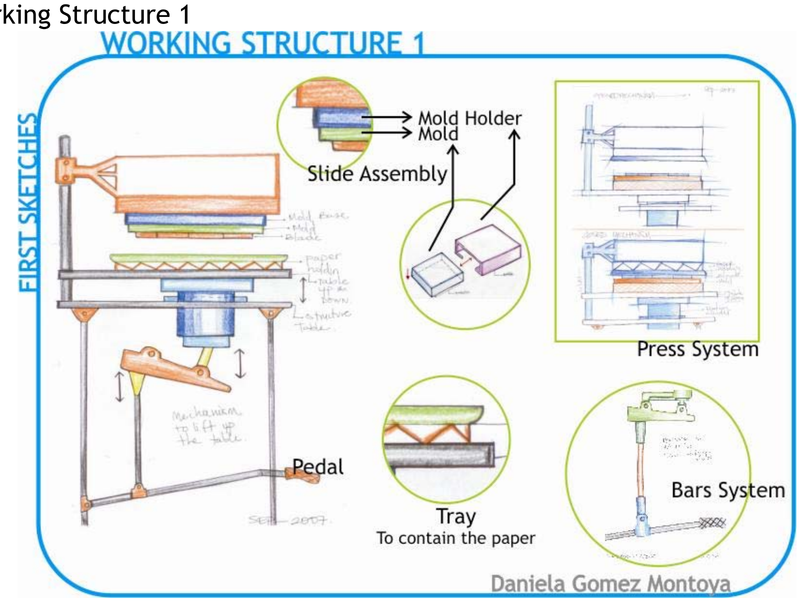
WORKING STRUCTURE 4
Crank + Rotary system flat die + Rack and pinion + Belt and pulley + Metallic Tray + Tray

WORKING STRUCTURE 5
Switch + Rotary system flat die + Electric motor + Matrix + Tray

WORKING STRUCTURE 6
Crank + Rotary system flat die + Gear + Matrix + Tray

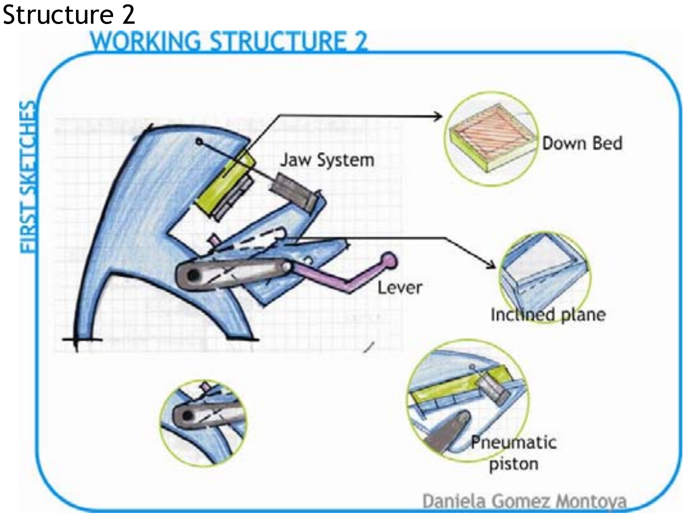
6.1.5 Working Structures: Possible Combinations. In the section 6.1.4 it was described verbally each Working Structure, result of the different combinations on the Morphologic Matrix. This section will show in a very brief and fast graphic way the hand-made sketches considered to start the process solutions. These are simple ideas or sketches, not very detailed, but they give an idea about how the configuration could be made and they are also a way to exercise the mind for the detailed design process.

Figure 35: Working Structure 1



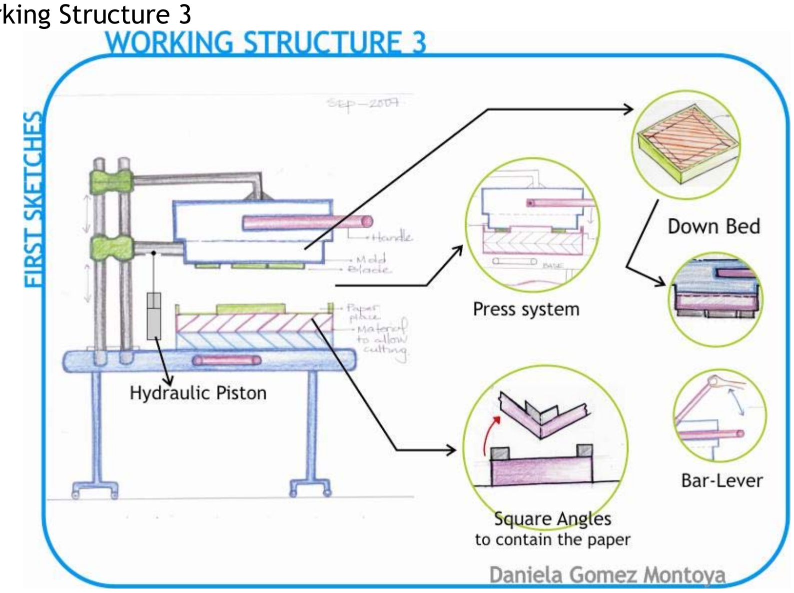
Own Elaboration

Figure 36: Working Structure 2



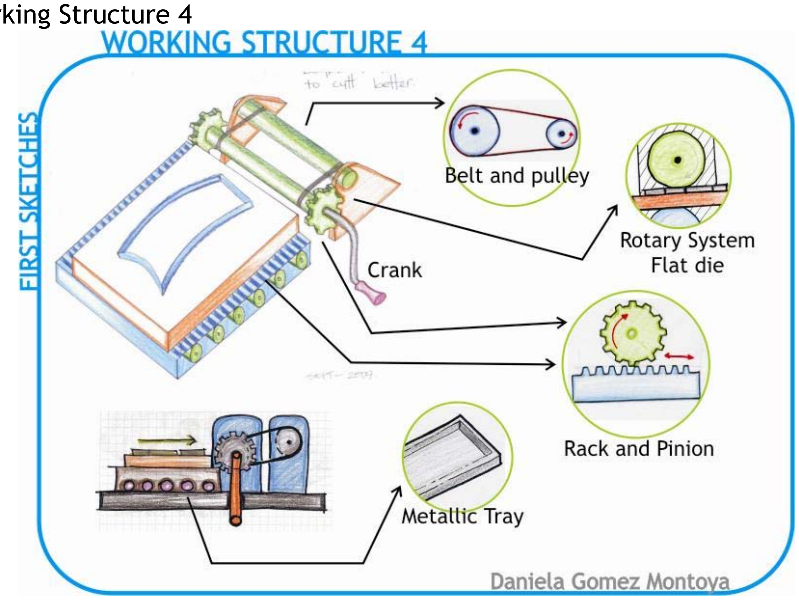
Own Elaboration

Figure 37: Working Structure 3



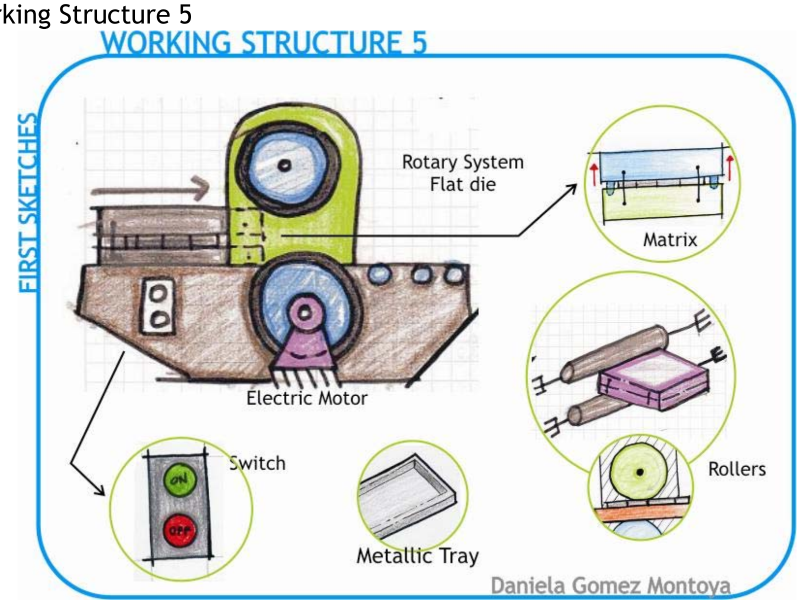
Own Elaboration

Figure 38: Working Structure 4



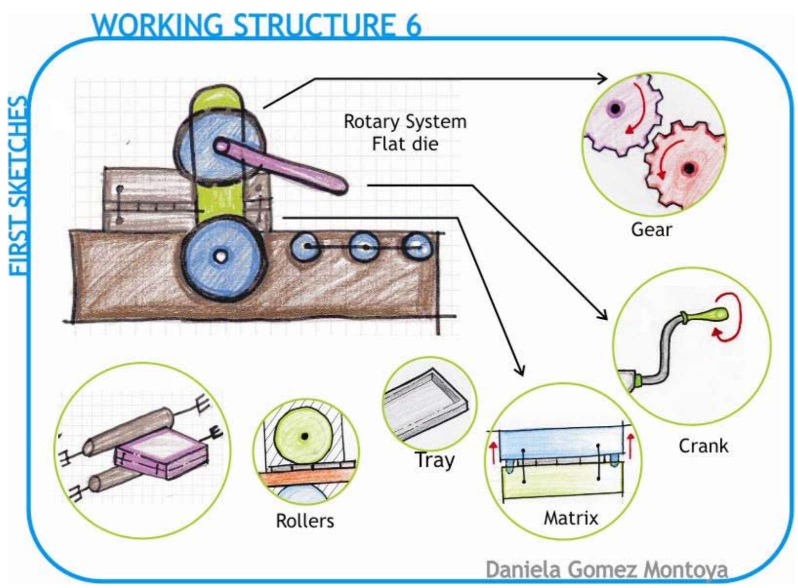
Own Elaboration

Figure 39: Working Structure 5



Own Elaboration

Figure 40: Working Structure 6



Own Elaboration

6.1.6 Working Structure Evaluation. In order to select the most suitable working structure or combination solution for a further and more detailed development, it is necessary to evaluate the six working structures from the previous stage. The objective basically is to find, according to an established criteria, which one of the options of combinations fills in a better way the requirements. The objective basically is to find, according to an established criteria, which one of the options of combinations fills in a better way the requirements, in this case given by the company and defined by the designer.

6.1.7 Evaluation criteria.

Mechanical Advantage: There are different mechanisms of movement that can give or produce better mechanical advantage than others. The **MA** is evaluated comparing the input force Vs the output force. This criterion is very important to be considered as the efficiency of the product and the comfortability of the operator, are closely related. The mechanical advantage should be as high as possible.
Manufacturing Process: The parts should be of easy consecution on the market, sing standard parts as much as possible. Those parts of special fabrication should have easy manufacturing processes.
Costs: This is one of the most important criteria for the company. The costs should be the lowest in order to facilitate the production of the machine and to improve considerably the current process at MR PRINT using the automatic machines.
Operations facilities: The way of operation of the product should make comfortable and easy the process for the user/operator.
Efficiency and effectiveness: The solution of the product should guarantee a good performance of the product in a functional perspective: die cutting and embossing process on an effective and efficient way.

Table 1: Evaluation criteria during conceptual phase

EVALUCATION PROCESS DURING THE CONCEPTUAL PHASE	
Criteria	Percentage %
Mechanical Advantage	20
Manufacture Process	10
Costs	20
Operation facilities	10
Efficiency and effectiveness	40
TOTAL	100

Own Elaboration

According to the VDI norm, each one of the previous criteria will be evaluated as follows:

Table 2: VDI Values

VDI	
Points	Meaning
0	Unsatisfactory
1	Just tolerable
2	Appropriate
3	Good
4	Very good

Own Elaboration

Valuation of each criterion:

Table 3: Criteria's Valuation

MECHANICAL ADVANTAGE	
Value	**Points**
Not enough force to develop the work.	0
Big effort little force.	1
Enough force with a considerably effort.	2
Good force, but the operator needs to apply a enough effort.	3
Good force, minimum operator's effort	4

MANUFACTURE PROCESS	
Value	**Points**
Difficult.	0
Complicated but can be done.	1
Normal.	2
Relatively easy.	3
Very easy to get or fabricate.	4

OPERATION FACILITIES	
Value	**Points**
Very difficult to operate.	0
Difficult to operate.	1
Normal Operation.	2
Relatively easy to operate.	3
Very easy to operate.	4

EFFICIENCY & EFFECTIVENESS	
Value	**Points**
Not efficient and effective	0
Just efficient and effective	2
Very efficient and effective	4

COSTS	
Value	**Points**
More than RM6000	0
RM5000 - RM6000	1
RM4000 - RM5000	2
RM3000 - RM4000	3
RM2000 - RM3000	4

Own Elaboration

6.1.8 Evaluation Matrix of working structures (WS).

The evaluation of the working structures will have the criteria in the following order:

A. **Mechanical Advantage**
B. **Manufacturing Process**
C. **Costs**
D. **Operation Facilities**
E. **Efficiency and Effectiveness**

The SCORE represents the valuation of each WS depending of each criterion. The TOTAL is calculated comparing the SCORE with the percentage of importance of the criteria. **TOTAL = SCORE x %**

Table 4: Evaluation Matrix

CRITERIA	WS 1			WS 2			WS 3			WS 4		
	Score	%	TOTAL	Score	%	TOTAL	Score	%	TOTAL	Score	%	TOTAL
A	3	0,2	0,6	2	0,2	0,4	2	0,2	0,4	4	0,2	0,8
B	2	0,1	0,2	2	0,1	0,2	2	0,1	0,2	3	0,1	0,3
C	3	0,2	0,6	1	0,2	0,2	3	0,2	0,6	3	0,2	0,6
D	4	0,1	0,4	3	0,1	0,3	3	0,1	0,3	4	0,1	0,4
E	3	0,4	1,2	2	0,4	0,8	2	0,4	0,8	4	0,4	1,6
			3			1,9			2,3			3,7

CRITERIA	WS 5			WS 6		
	Score	%	TOTAL	Score	%	TOTAL
A	4	0,2	0,8	4	0,2	0,8
B	3	0,1	0,3	3	0,1	0,3
C	3	0,2	0,6	3	0,2	0,6
D	4	0,1	0,4	3	0,1	0,3
E	4	0,4	1,6	4	0,4	1,6
			3,7			**3,6**

Own Elaboration

6.1.9 Comparison with the IDEAL WORKING STRUCTURE.

The objective is to obtain the Technical Index (TI) in order to compare the Working Structure selected (WS 6) with the Ideal WS.

TI= Total WS 6/ Total Ideal WS

The TI should be from 75% to 85% to have a valid WS selected.

Table 5: Comparison with the Ideal WS

Criteria	IDEAL WS	WS 6
Mechanical Advantage	4	4
Manufacture Process	4	3
Costs	4	3
Operation facilities	4	3
Efficiency and effectiveness	4	4
TOTAL	**20**	**17**

Own Elaboration

IT= 17/20 = 0.85 = 85%

With a TI of 85% of validity, the "**WS 6**" is good option to be developed as a final alternative for the project. The evaluation Matrix is considering all the percentages (weights) given previously to the criteria, where "**WS 6**" is the closest option to an ideal solution, with the highest score: **3.6.**

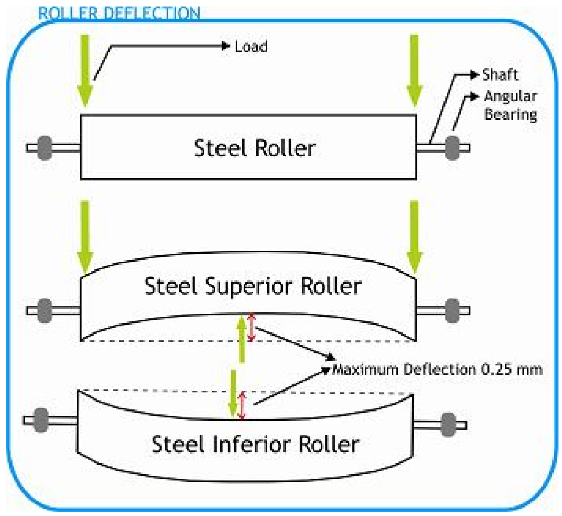
Taking as a reference the **"WS 6"** the following steps are to develop the design ideas following the working principles combination to, finally, find the definitive solution. This does not mean that **"WS 6"** is the absolute and most complete solution; the design process continues to improve and think in more options and possibilities for the idea until the detail design is done. (See **Annex No. 11**)

6.1.10 Exploration and options for WS 6. Once the final Working Structure has been selected, it can describe and define the rest of the configuration to have a complete idea developed. The product will be operated by a crank (See *Annex No. 8)*.

The functional mechanism will be a rotary system. The final decision about whether to use two or three rollers depends of the *"Beam Load analysis"*[10] that will let us know how much, the deflection of the roller that applies the pressure, is. The maximum deflection of the system (two rollers) could not be more than 0.5mm, it means 0,25 mm each roller, other wise the paper will not be cut or embossed. This value comes from the fact that the cutting knives, during the cutting process, are inserted on the cutting board, due to the pressure 0,5mm[11].

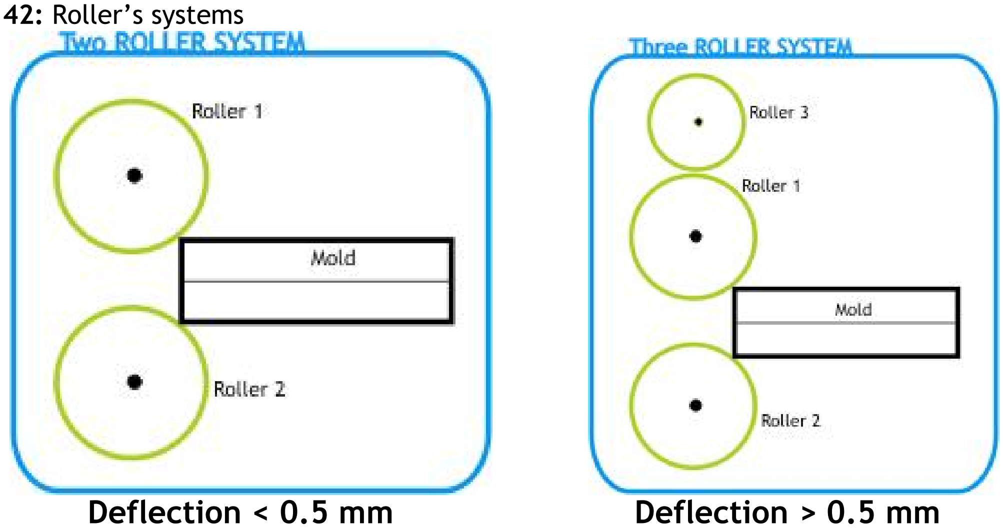
[10] Analysis developed on the engineering **Annex No. 10**.
[11] Die-Cutting Test.

Figure 41: Roller's Deflection



Own Elaboration

Figure 42: Roller's systems



Own Elaboration

The use of gears seems to be the most suitable mechanism. This will be analyzed furthermore, during the next chapter. The top roller will be adjustable in order to graduate how much pressure is applied over the die mold. The use of two independent Power Screws at both ends will allow the roller's graduation. This system is useful as well, in situations when is needed to apply stronger pressure at one of the ends, due to the knives shape[12].

[12] Analysis developed on the engineering **Annex No. 10**.

6.2 DESIGN PROCESS

According to the CONCEPTUAL DESIGN process and its final evaluation, the **"WS 6"** is the best structure to be developed. During this section the design process is described considering the following aspects: engineering, user, shape and aesthetic, cost.

It is important to make clear that the proposed working structure to develop does not exist currently in the market, as what is needed is manual machine for an industrial use: 8 hours a day, 7 days of the week.

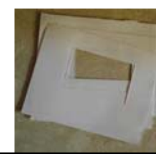
The current manual machines found during the market analysis phase are all designed for kids and teenager's handicraft use.

6.2.1 Preliminary tests. Before starting with the design process in terms of engineering, there are some tests that need to be designed and performance in order to know the behaviour of the system and the values of reference. The most important aspect in this case, is the cutting and embossing force. This is the principal parameter to consider and it will define in a high level the geometry, specifications and dimensions of the parts of the product. During the following section it would be clear the importance of this area to the project. These test were done at the Materials Laboratory of EAFIT university.

- **Paper Compression Test: Die-Cutting Force test - Shear Strength of paper**

It is very important to now how much pressure we need to apply to cut the most common papers used at the company, but MR PRINT does not have the specific information. By the other hand, there is not any technical information about the "shear strength of the paper". The **Annex No.3** presents in detail the process made to do the test. The final results are shown on the following table:

Table 6: Die-Cutting force test results

PAPER	FORCE	PICTURE
Bond (75 GSM)	8,35 KN	
CardBoard 1 (180 GSM)	8,80 KN	
CardBoard 2 (340 GSM)	9,20 KN	
Bond (5 sheets of paper)	10 KN	
Bond (10 sheets of paper)	16,8 KN	MAXIMUM

Own Elaboration

As a conclusion, the worst scenario is cutting 10 sheets on paper (BOND) requiring a force of **16,8 KN.** This case is not going to happen, as the company express on the PDS that it will cut 1 sheet of paper at the time.

❖ Paper Compression Test: Emboss Force test

Once the paper shear strength test has been done, giving us as a result a maximum force of 16,8 KN; this test of embossing is done, using only the paper that required more force (BOND paper), in order to confirm if it is necessary a higher force to embosses it. The **Annex No.4** presents in detail the process made to do the test. The final results are shown on the following table:

Table 7: Embossing force test results

DESCRIPTION	FORCE	CONCLUSION
Bond (75 GSM) 1 Sheet	500 N	No Emboss
Bond (75 GSM) 1 Sheet	1 KN	Emboss very smooth, not so clear.
Bond (75 GSM) 1 Sheet	1,5 KN	Emboss smooth, still not so clear.
Bond (75 GSM) 1 Sheet	2 KN	Emboss correctly!
Bond (75 GSM) 2 Sheet	2 KN	No Emboss
Bond (75 GSM) 2 Sheet	3 KN	Emboss smooth, not so clear.
Bond (75 GSM) 2 Sheet	4 KN	Emboss correctly!

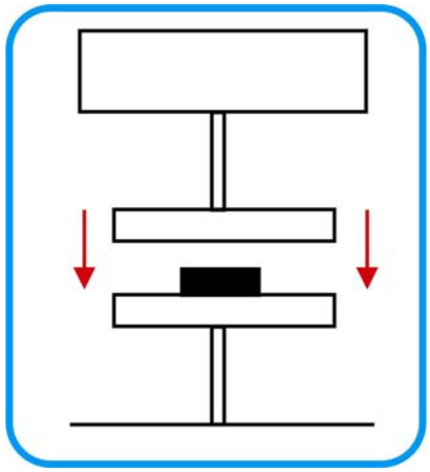
Own Elaboration

As it has been showed, the embossing force is not higher than the Die-cutting force. This means that the maximum force used as a reference for the following steps will be the die-cutting force.

❖ Compression Test: Cork (sponge) to eject the paper from the mold

It is very important to now how much pressure we need to apply to compress the cork 6 mm (this is the normal compression in the current process at the company), but MR PRINT does not have any information about the mechanical properties of the material and its behavior. The following figure shows the diagram of the test situation. The **Annex No.3** presents in detail the process made to do the test. The final results are shown:

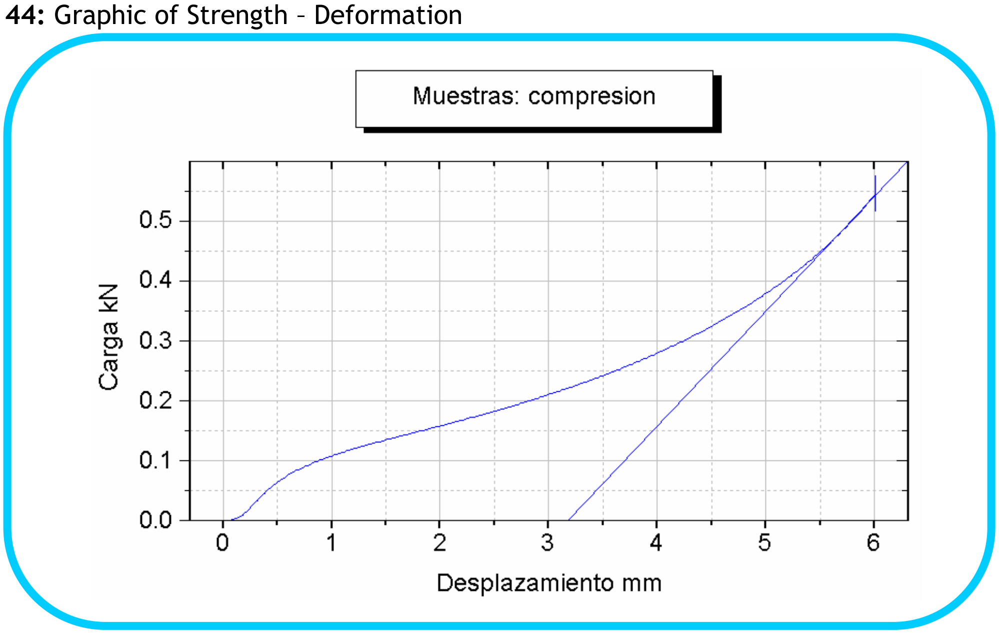
Figure 43: Diagram of the test



Own Elaboration

To compress the cork of (1169 mm²) area, **<u>6mm</u>** it is necessary to apply a force of **0.545 KN (545 Newton).** This force in minimum compared with the system force of 16,8 KN. The following figure shows the graphic of Strength – Deformation.

Figure 44: Graphic of Strength – Deformation

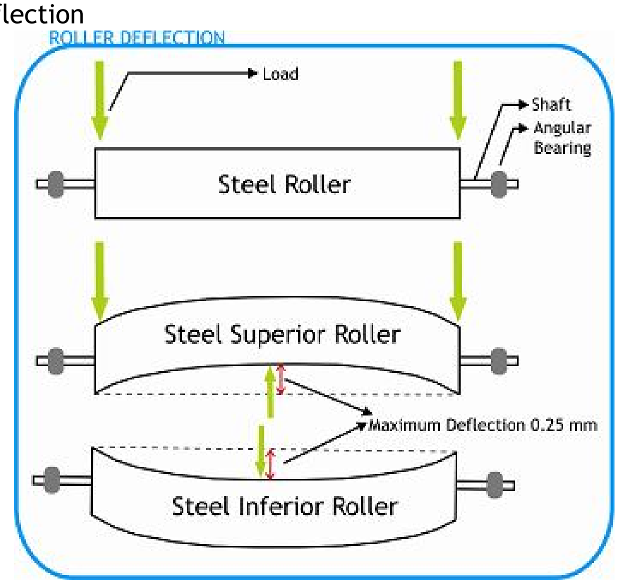


Own Elaboration

6.2.2 Engineering considerations and calculations. This section is a brief of all the engineering considerations for the critical elements that require calculations, basically of their resistance, in order to validate the behaviour on the design, due to the specifications and geometry.
The objective here is to guarantee a good performance of the product at all times. The complete analysis is on the **Annex No. 10.**

❖ Determination of the cross section of the main rollers by their resistance (Roller's size)
With this analysis, the size of the steel main rollers is going to be defined. It is important to know, as well, weather if the design will have two or three rollers. The principle during this calculation is: The maximum admissible deflection of the rollers at its centre point is **0.5mm,** which means that each roller (superior and lower roller) could be deflected 0,25 mm maximum[13], as it is shown on the following figure:

Figure 45: Roller's Deflection



Own Elaboration

This limit of 0,5 mm corresponds to the insertion of the cutting knives in the press board (considering the current process at the company). If the roller's deflection is over this value, then the cutting job is not well done.

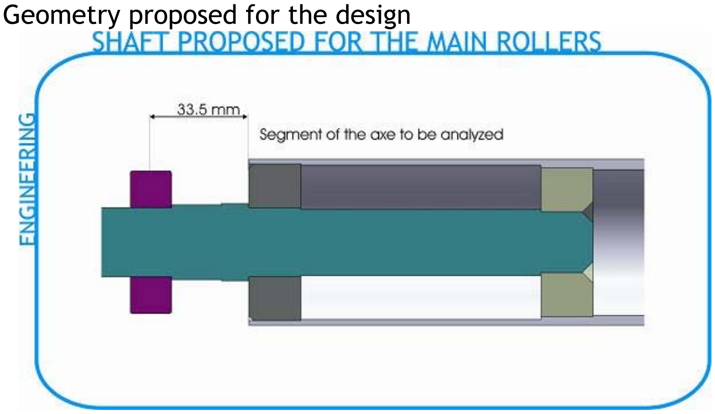
[13] In order to guarantee a correct cutting job, the knife is being inserted in the cutting board no more than 0,5mm. If the roller is deflected more than this condition, then the paper in not going to be cut correctly.

After a *Beam Load analysis* (*BLODGETT,2002*) (**Beam supported at both ends, uniform load partially distributed over span**), the Moment of Inertia **(I)** was found, in order to define the geometry of the rollers when the maximum deflection is 0,25 mm (admissible value for each roller). As a result: **I=** 27,7 cm^4. Knowing this value, it is possible to find the closest value **(28,5 cm^4)** on the steel catalogue[14] the right specification: **a tube of outside diameter 60.5 mm, wall thickness 4 mm** will be enough and it won't deflect more than 0.25 mm for each roller. For **I=28,5 cm^4** the deflection is certainly 0,24 mm which can conclude that the design will need only two rollers.

❖ Validation of the Main Rollers shaft's resistance (Calculus of the Security Factor)

In order to know if the proposed shaft for the main roller will resist to the forces once the product is working, the following calculation is necessary, to know the value of the "*Security Factor*"[15] and prove that the calculation is correctly and secure to be trusted. This calculation is made considering the space of the shaft between the bearing and the roller, as it is shown on the following figure:

Figure 46: Shaft's Geometry proposed for the design



Own Elaboration

After a *Beam Load analysis* (*BLODGETT,2002*) where the model is basically a **Cantilever: Beam supported at one end only, concentrated load at free end,** the analysis made is:

[14] HIAPTECK GROUP, Malaysia. Steel Tubes Catalogue.
[15] The Security Factor is a value used in engineering calculations to guarantee the performance of the element being tested. The result of the calculus is multiplied by this value to assure that it is being considered in higher risk level.

Mmax= Maximum Momentum = 138,30 Nm

$$\mathbf{Mmax} = R \times L = 8331{,}5\ N \times 0{,}0166\ m = \mathbf{138{,}30\ Nm}$$

SD = Shaft's Diameter = 28mm = 0,028m
It is assumed that shaft is a cylinder without scales, and the value represents the smallest value of the sections.
R = Reaction = 8331, 5 N
TS = Tensile Strength = 310 Mpa = 310000000 Pa
MS = Modulus of Section = 2155 mm^3 = 2,155 x 10^-6 m^3
L= Length = 0,0166 m
N= Security Factor =???

$$\boxed{\begin{array}{c}\mathbf{Mmax / MS = TS / N} \\ \mathbf{N = (TS \times MS) / Mmax}\end{array}}$$

$$\mathbf{N} = (310000000\ Pa \times 2{,}155 \times 10^{-6}\ m^3) / 138{,}30\ Nm$$

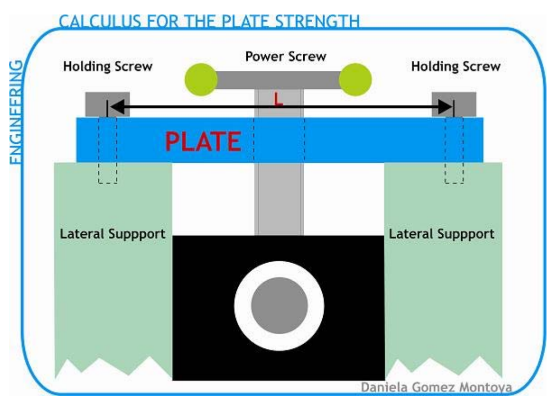
$$\mathbf{N = 4{,}83} \longrightarrow \mathbf{GOOD!}$$

As a conclusion, with a Security Factor of 1,869, it is possible to assure a good performance of the shaft, as it can resist 1,869 times the maximum load.

❖ Validation of the Security Factor of the Power Screw's plate to check its resistance

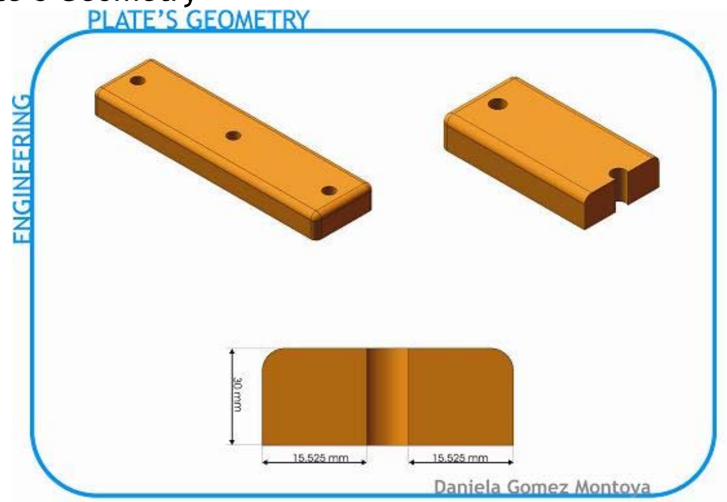
During this section it is going to be defined if the proposed dimensions for the plate that support the Power Screw and its axial efforts, will work properly. As the plate is supported at both ends with screws and the Power Screw is making a pressure down, the plate will need to resist this force without deflection (**See Figure 47 and 48**). The criteria for conclusion will be the Security Factor result.

Figure 47: Diagram of the power screw's plate



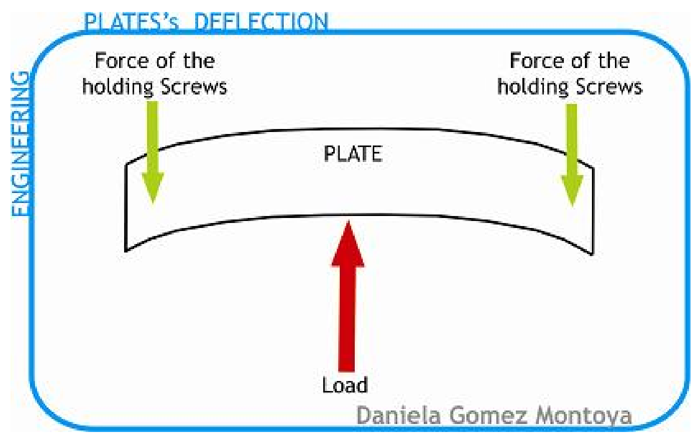
Own Elaboration

Figure 48: Plate's Geometry



Own Elaboration

Figure 49: Plate's Deflection



Own Elaboration

After a *Beam Load analysis (BLODGETT, 2002)* where the model is basically a **Beam fixed at both ends. Concentrated load at mid-span,** the analysis made is:

Mmax= Maximum Momentum = 213,49 Nm

Mmax = (R x L)/8 = (8331,5 N x 0,205 m)/8 = **213,49 Nm**

Dimensions of the Transversal Section of the plate = 0,015525 m x 0,03 m
R = Reaction = 8331, 5 N
TS = Tensile Strength = 205 Mpa = 205000000 Pa
MS = Modulus of Section = 4657,5 mm^3 =4,65 x 10^-6 m^3
L= Length = 0,205 m
N= Security Factor =???

$$\boxed{\begin{array}{c} Mmax / MS = TS / N \\ N = (TS \times MS) / Mmax \end{array}}$$

N= (205000000 Pa x 4,65 x 10^-6 m^3) /213,49 Nm
N= 4,46 ⟶ **VERY GOOD**

This result shows a very good Security Factor, that guarantees an excellent performance and behaviour of the proposed plate, according to its geometry.

❖ Gear's calculations

A **gear** is a component within a transmission device that transmits rotational force to another gear or device. According to the proposed design of the product and its function, the system to be used for the transmission is a simple gear system, "Spur Gears"[16]. The initial step was to select an approximate diameter for the pinion[17] and the gear[18] in order to consider the geometry and design of the product. It is important to note that the speed for the pinion is 60 rpm, considering that the crank will turn at 1 revolution per second. The relation of transmission will be 2:1, which means that two turning of the pinion correspond to a one turning of the gear. In other words, the gear will turn at 30 rpm. The catalogue of reference will be from the producer "ENGRANAJES MIRALLES"[19]

M = Dp/Z **P=** π x M **Z=** Dp/M
CD= (Dp1 +Dp2) /2
Tooth's Foot = 1,25 x M **Tooths' Head** = M

According to the product's geometry, the initial idea was to use a Pinion with a Primitive Diameter of 45 mm and a Gear of 90 mm:

[16] Spur gears are the simplest, and probably most common, type of gear. Their general form is a cylinder or disk. The teeth project radially, and with these "*straight-cut gears*", the leading edges of the teeth are aligned parallel to the axis of rotation. These gears can only mesh correctly if they are fitted to parallel axles
[17] Smallest gear attached to the crank.
[18] Biggest Gear.
[19] ENGRANAJES MIRALLES. [Internet Article]. http://www.engranajesmiralles.com/Engramir5.htm

Dp1= 90mm **Dp2**= 45mm

Z1 = 38 **Z2** = 19

Due to these considerations, we have:

M = 90mm/38 = 2,368 mm or **M**= 45mm/19 = 2,368 mm

There are standard Modulus defined to select the gear and pinion. According to the MIRALLES catalogue the closest standard Modulus is 2. The selection of the gear system was base on those tables, to see the complete process please refer to *Annex No. 7.* According to the catalogue, the final dimension for the gear and pinion are:

GEAR:

Z1 = 40 **Dp1** = 80 mm **De1** = 84 mm **Daxis1** = 14 mm

PINION:

Z2 = 20 **Dp2** = 40 mm **De2** = 44 mm **Daxis2** = 10 mm

P= π x M **P**= π x 2,3684 P= 7,44 mm

CD= (Dp1 +Dp2) /2 **CD** = (80 mm +40 mm)/2 **CD=60 mm**

Tooth's Foot = 1,25 x M = 1,25 x 2,3684 mm = 2,96 mm

Tooths' Head = M = 2,3684 mm

Finally, it is important to know the lineal speed of the matrix of the mold that pass through the rollers as follow:

The gear speed is: 30 rpm

Converting this value to Angular Speed, rad/s we have:

30 rpm x (2π rad/s)/60 rpm = **3,14 rad/s**

The value of the Angular Speed multiplied by the radius of the roller is the Lineal Speed of the matrix:

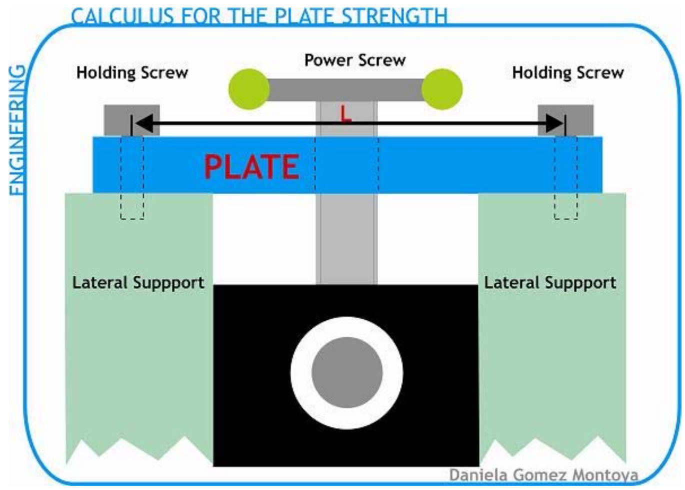
3,14 rad/s x (60,5 mm / 2) = **95 mm/s**

❖ Power Screw Validation

The Power Screws are highly used to transfer or transmit movement in a soft and uniform way. They can transform rotary in lineal movement. The difference with normal screws is that the Power Screws are movement devices, and the others are normally used to join parts. In this case, the Power Screws (2) are going to be used to adjust the superior roller, against the matrix, in order to guarantee the force to be applied to make the cutting or embossing.

The proposed Power Screw to use, according to the geometry of the product and its function is a **3/4 - 6 Acme - 2G.** The **Figure 50** shows a diagram of the use situation for the Power Screw. The idea is to allow the movement of the superior roller and adjust it against the matrix giving it enough pressure to guarantee the cutting and embossing process.

Figure 50: Diagram of the power screw's plate



Own Elaboration

There are two kind of analysis that were done to validate the screw for the proposed design:

❖ Design of Compression Members: "Column" of the Power Screw

This analysis is made to check load machinery elements exposed to a compression load. This is important as the length of the proposed power screw (**3/4 - 6 Acme - 2G**) is big compare with his diameter, so its resistance needs to be validate, in case of an overload situation. To define the element condition to be analysed, the book *"DESIGN OF WELDED STRUCTURES"* was used as a source of information for the analysis of the column of the Power Screw. The objective of this analysis is to define the *Critical Load value*, in order to know if the system load is lower to the load that the column of the power screw (its length in relation to its diameter) can support before deflection. The system load for each screw is **8331,5 N.**

J.B JHONSON EQUATION

Pcr = A Sy (1 – (Q/(4 r^2)) Where: **Q= (Sy L^2) / (n π^2 E)**

Pcr = Critical Load
D= Diameter of the transversal section = **16,93 mm = 0,01693 m**
A = Area of the transversal section = **225 mm^2 =0,000225 m^2**
Sy = Tensile Strength yield = **205000000 Pa**
r = Minimum turning radius of the transversal section = 16,93 mm/4 =
4,23 mm = 0,00423 m
E = Modulus of elasticity = 200 Gpa = **200 x 10^9 Pa**
L= Column Length= **74,5 mm = 0,0745**
n = Coefficient of the ends conditions: one end fixed and the other free, but guided = **2**[20]

Q= (Sy L^2) / (n π^2 E) = (205000000 x 0,0745^2)/(2 x π^2 x 200 x 10^9 Pa)
Q= 2,88 x 10^-7

EULER= Pcr = A Sy (1 – (Q/(4 r^2)
Pcr = (0,000225 x 205000000) (1-(2,88 x 10^-7/4 x 0,00423^2)

Pcr = 45939,26 N

Knowing the Critical Load that the Power Screw of 3/14" can support, the Security Factor can be found as follow:

45939,26 N / 8331,5 N = 5,51 ⟶ **GOOD!**

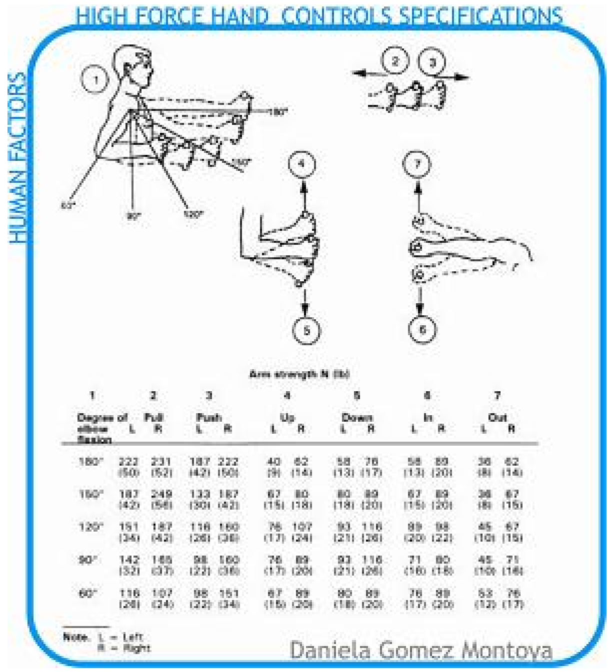
As a conclusion, the Power Screw's specifications are very good defined, according to the system conditions.

❖ Hand force Validation

This analysis will let us know if the force that the operator need to apply to power screw is suitable according to ergonomic parameters and it will define the dimension of the lever to operate the screw. To define the element condition to be analysed, the book *"DISEÑO DE MÁQUINAS, TEORÍA Y PRÁCTICA"(* DEUTSCHMAN *,1995,15)* was used as a source of information for the analysis of Power Screw. The objective of this analysis is to define the force required to operate and move the Power Screw, taking as a reference an Anthropometric Value, which says the maximum force that can be apply by a human hand: 222 N for the right hand. The idea is to find a lower value, defining the correct dimension for the lever's radius.

[20] Pre- fixed value. MANUAL UNIVERSAL DE LA TECNICA MECANICA, Volume 1.

Figure 51: High Force of the Hand



Own Elaboration

The momentum for the situation was found on the whole process of the calculation as:

$$M = F \times R \times \tan(\alpha + \varphi)$$

$$M = 8331{,}5\ N \times 1{,}847 \times 10^{-3}\ m \times \tan(4{,}33^\circ + 19{,}01^\circ)$$ [21]

$$\boxed{\mathbf{M = 5{,}91\ Nm}}$$

Once it is known the value for the momentum, it is possible to know the hand's force to operate the Power Screw, with the following relation:

$$\mathbf{F = M/Y}$$

Where **Y=** is the lever's radius, **F=** the resulting force and **M=** Momentum.

If **Y=** 0,10 m, **F=** 5,91 Nm / 0,10 m = **59,1 N = GOOD!**
If **Y=** 0,15 m, **F=** 5,91 Nm / 0,15 m = **39,4 N = GOOD!**

As a conclusion, a good diameter for the lever to operate the screw, in order to guarantee an adequate applied force by the operator's hand is 0,10m.

[21] See **Annex No. 10**

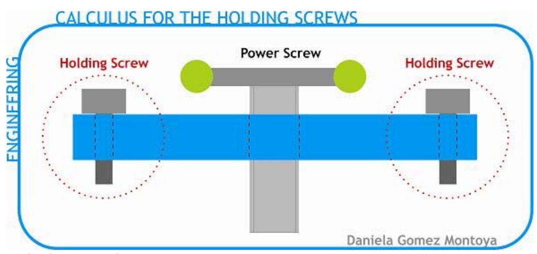
❖ Definition of the holding screws to join the plate of the Power Screws to the lateral supports.

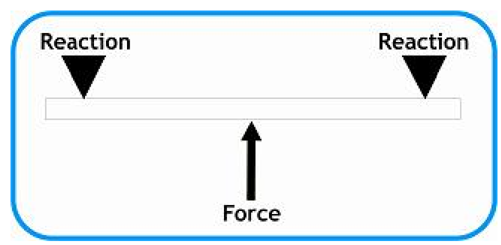
In order to know if the proposed screws to hold the plate to the lateral supports, are strong enough, the following calculation is necessary, to know the value of the "*Security Factor*"[22] and prove that the calculation is correctly and secure to be trusted. The failure criteria used in this case to define the specifications to select the screws is basically "Pure Tensile Strength". This selection was made using the book "*DISEÑO EN INGENIERÍA MECÁNICA*"[23]. According to product's geometry it is proposed to use a screw aesthetically accorded with the following characteristics, for the joining of the plate to the lateral supports:

Metric system screw: M10 - 5,8 class of property[24]

Added to the analysis of the previous proposed screw, you will find afterwards, some more types of screws (in denomination or material) analysed, in order to make a comparison and have options to choose.

Figure 52 and 53: Calculus for the Holding Screws - Diagram of the beam, according to the case





Own Elaboration

After a *Beam Load analysis,* where the model is basically a **Beam supported at both ends. Concentrated load at mid-span,** the analysis made is:

Rb = R/2 **Rb** = 8331,5 N/2 **Rb = 4165,75 N**

G= F/A **G** = Rb/A

- **Security Factor Analysis Proposed screw 1: Metric system screw: M10 – 5,8 class of property**[25]

  G= 4165,75 N / 0,0000523 m^2 **G** = 79651051,63 Pa

[22] The Security Factor is a value used in engineering calculations to guarantee the performance of the element being tested. The result of the calculus is multiplied by this value to assure that it is being considered in higher risk level.
[23] SHIGLEY, Joseph Edward. DISEÑO EN INGENIERÍA MECÁNICA. Mc Graw Hill. Fifth Edition
[24] Medium Steel, low Carbon.
[25] Medium Steel, low Carbon.

G= 79,65 Mpa < 380 Mpa

N= 380 Mpa / 79,65 Mpa **N = 4,77 GOOD!!!**

- **Security Factor Analysis Proposed screw 1: Metric system screw: M8 - 5,8 class of property**[26]

G= 4165,75 N / 0,0000328 m^2 **G** = 127004573,32 Pa

G= 127 Mpa < 380 Mpa

N= 380 Mpa / 127 Mpa **N = 2,99 GOOD!!!**

- *Security Factor Analysis Proposed screw 1:* **Metric system screw: M12 - 5,8 class of property**[27]

G= 4165,75 N / 0,0000763 m^2 **G** = 54596985,58 Pa

G= 54,59 Mpa < 380 Mpa

N= 380 Mpa / 54,59 Mpa **N = 6,96 GOOD!!!**

As a conclusion, any of three proposed screws or their equivalent in ANSI or any other standard system is good for the proposed use.

Screws **Class of property 4,6** where Minimum Tensile Strength Limit (TR) is 225 MPa or **Class of property 4,8** where Minimum Tensile Strength Limit (TR) is 310 MPa, are good for the use proposed based on the results of the previous analysis where we used M8, M10 and M12 screws. The following Classes are good as well, as their TR is higher.

❖ Spring Validation

The function of the springs located on the plate that supports the Power Screw, is to control the pressure apply to the roller through the Power Screw, in order to protect the system of an overload and damage. The calculation or validation is based on the deformation that the springs can support with the system load.

[26] Medium Steel, low Carbon.
[27] Medium Steel, low Carbon.

To define the element condition to be analysed, the book of OBERG, E. was used as a source of information. The units for this analysis are inches, Lb and PSI. The proposed spring to be validated is a Die-set spring, with rectangular section, pitch of 6.35 mm. The equation and calculations for the deformation for a specified load **P** are:

$$f = 7{,}2\ \pi\ r^3\ P\ (b^2 + h^2) /\ b^3\ h^3\ G$$

The value of **P** is considered with an addition of a 10% more, as a security factor.

Deformation Analysis

P= Specified Load = 4582, 325 N = 1028, 68 Lb

f= Deformation for an specific Load (P)

G= Modulus of rigidity = 200 Gpa = 29007547,546 PSI

b= Biggest dimension of the rectangular transversal section of the spring.

b= 4,76 mm = 0,187 Inches

h= Smallest dimension of the rectangular transversal section of the spring.

h= 3,175 mm = 0,125 Inches

r= Radius of the spring (Primitive) = 9,5875 mm = 0,377 Inches

$$f = 7{,}2\ \pi\ r^3\ P\ (b^2 + h^2) /\ b^3\ h^3\ G$$

$$f = (7{,}2 \times \pi \times 0{,}377^3 \times 1028{,}68\ (0{,}187^2 + 0{,}125^2)) /$$

$$0{,}187^3 \times 0{,}125^3 \times 29007547{,}546$$

f= 0,170 Inches = 4,325 mm = GOOD!

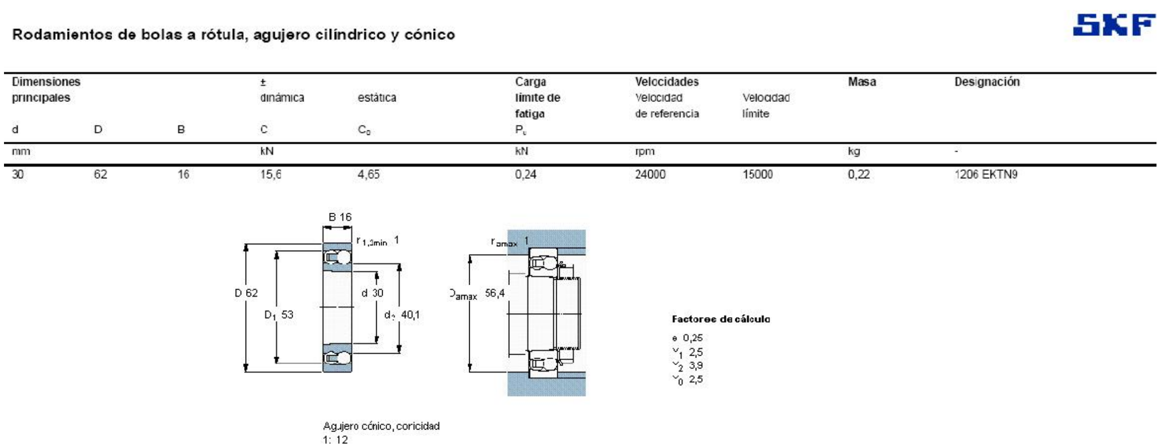
The geometry and specification of the proposed spring are OK for the purpose of use.

❖ Determination of Bearings for the main roller

Considering the height graduation of the roller, with a power screw at both ends, the bearings used need to allow a movement not-aligned while the roller is graduated. For this purpose the kind of bearing selected, according to SKF's catalogue[28] (one of the biggest bearing producers in the world) was: Self – Aligning Ball Bearings. The self-aligning ball bearing was invented by SKF. It has two rows of balls and a common concave sphered raceway in the outer ring. The bearing is consequently self-aligning and insensitive to angular misalignments of the shaft relative to the housing. It is particularly suitable for applications where considerable shaft deflections or misalignment are to be expected. Additionally, the self-aligning ball bearing has the lowest friction of all rolling bearings, which enables it to run cooler even at high speeds.[29]

From this category, the bearing was selected from the "Basic Design" reference 1206 ETN9, as follows:

Figure 54: Self-Aligning ball bearing. 1206


Rodamientos de bolas a rótula, agujero cilíndrico y cónico

Dimensiones principales			± dinámica	estática	Carga límite de fatiga	Velocidades Velocidad de referencia	Velocidad límite	Masa	Designación
d	D	B	C	C_0	P_u				
mm			kN		kN	rpm		kg	-
30	62	16	15,6	4,65	0,24	24000	15000	0,22	1206 EKTN9

SKF

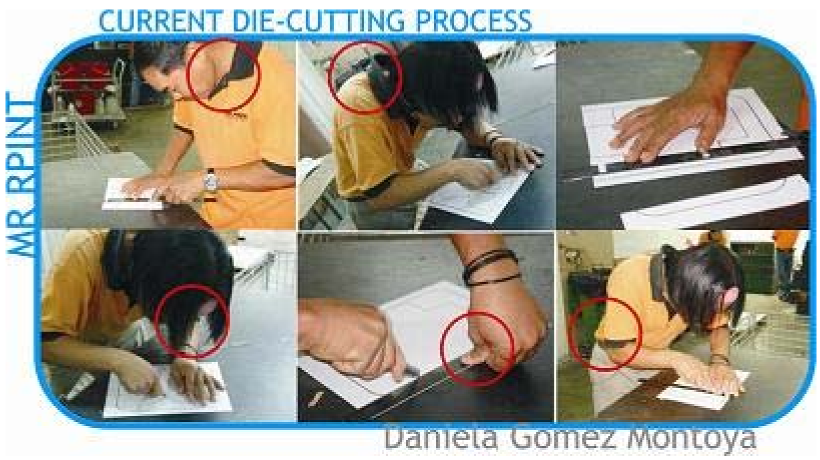
This specified reference of bearing can support 15,6 KN by itself[30], even though there are going to be used one bearing at each end of the roller, meaning that the load will be shared by both. It is important to remember that the system load for each end is 8.3315 KN (previously calculated), which means that the proposed bearings are O.K for the design.

[28] SKF. Self-Aligning ball bearings. [Internet article]. http://www.skf.com/portal/skf/home/products?maincatalogue=1&lang=en&newlink=1_2_2 [February 20th 2008].
[29] Ibid. SKF.
[30] During the last section the maximum load was defined by tests of paper shear strength as almost 17 KN.

6.2.3 User and Ergonomic Analysis. The design of an industrial product involves some issues related with the person who is going to do the operation and manipulation of such a product. In our case, one of the main objectives is to improve the current process of the company as this process is not only being inefficient (time, quality, material)[31], but also very unsafe and uncomfortable for the operator. The complete process of this phase is described in the **Annex No. 8,** as here only are presented the principal ideas.

❖ **Analysis of the user during the current process at the company**

Figure 55: Board Of the current Die-Cutting process



Own Elaboration

The Figure 55, represents the positions and postures that the operators are using when they need to cut different shapes by hand. The red circles are showing wrong postures that are not only uncomfortable, but also not recommended for the health in a medium and long future.

[31] Situation explained in detail in chapter 5.

Figure 56: Board of Operation of different products.

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The Board showed on the Figure 56 is useful to consider and analyse many aspects related with the operator in an industrial environment. As it was concluded on the previous section the comfortability, safety, clarity of vision and easy operation are inherent requirements to involve in the product.

- The most important part of the body to take care and prevent for diseases is the vertebral column. The product should guarantee the right position, relating the visual angle, the height from the floor to the crank, and the distance to facilitate the set up of the matrix with the mold and the paper.

- The blades and knives should not be exposed without protection as the operator could be in risk on cutting himself in a wrong movement.

- The operator should have the possibility to work either sitting down or on his foot, this could make him feel comfortable and change position every time he needs it.

- As the cutting and embossing activities can be done by women or men with different body complexions (height, weight, etc) the product should be able to be graduated in height. This allows to everybody the use of the machine without any problem.

In this case only the Die-cutting process is analysed as it is sometimes done by hand. For the embossing an automatic machine is used. As an added value our product will not only do die-cutting, but also embossing for paper in different thickness.

❖ Anthropometry and biomechanics

The **"Human Factors Design Guide"** (WAGNER,1996) was used as a theory reference for the human factor analysis. Designers and human factors specialists incorporate scientific data on human physical capabilities into the design of systems and equipment. Human physical characteristics, unlike those of machines, cannot be designed. However, design oversight can place unnecessary demands and restrictions upon user personnel.

o Anthropometry

It is the scientific measurement and collection of data about human physical characteristics and the application (engineering anthropometry) of these data in the design and evaluation of systems, equipment, manufactured products, human-made environments, and facilities.

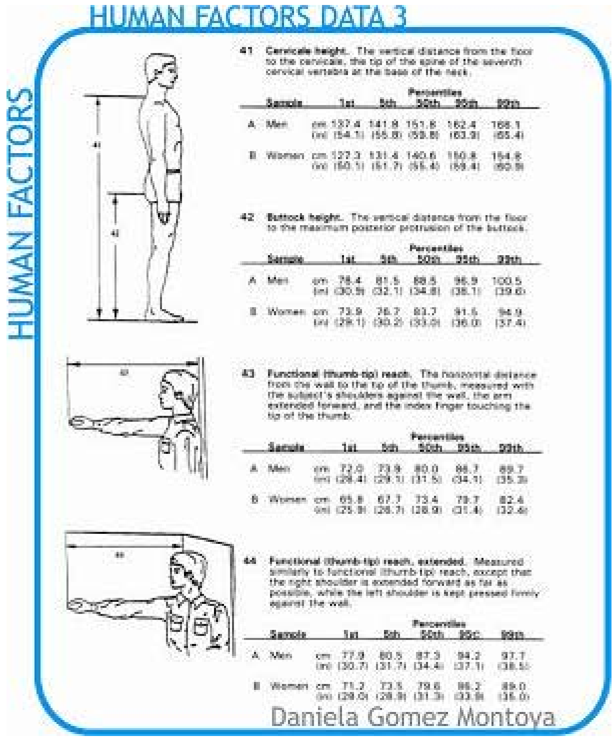
o Biomechanics

It describes the mechanical characteristics of biological systems, in this case the human body, in terms of physical measures and mechanical models. This field is interdisciplinary (mainly anthropometry, mechanics, physiology, and engineering). Its applications address mechanical structure, strength, and mobility of humans for engineering purposes. Anthropometric and biomechanics data shall be used in the design of systems, equipment (including personal protection equipment), clothing, workplaces, passageways, controls, access openings, and tools.

o Anthropometric and biomechanics data

During this section is presented the most relevant data useful for the project. Based on this information and according to the right percentile choice, the product's dimensions are defined, for more details please refer to *Annex 8*. The following figure is just an example of the useful information for the project that can be found on the *Annex 8*.

Figure 57: Human Factors data 3



WAGNER@1996

❖ **Handle characteristics (WAGNER,1996)**
- o Handle comfort
- o Handle surface
- o Handle conductivity
- o Handle attachment
- o Recessed, hinged, and folding handles
- o Stops for hinged or folding handles
- o Handle Dimensions

For the product, the best option is using a crank for the operation. This is due to the size of the machine and the transmission system for the movement of the rollers. It is used when multiple rotations are required; fast; can handle high forces, with proper gearing can be use for either gross or fine positioning over a wide range of adjustments. The crank also offers the possibility to use any of both hands, at any of both sides of the machine depending of the person who is operating it.

❖ Cranks

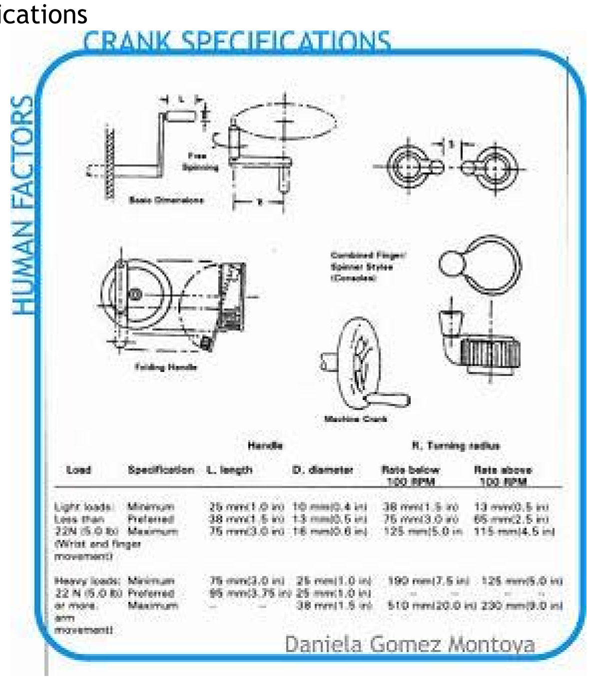
o Crank specifications

The dimensions, resistance, and separation of adjacent circular swept areas of cranks shall not exceed the maximum and minimum values given in the **Figure 58.**

o When to use

Cranks should be used for any task that requires many rotations of a control, particularly if high rates or large forces are involved. For tasks that involve large slewing movements as well as small, fine adjustments, a crank handle may be mounted on a knob or handwheel. The crank would then be used for slewing and the knob or handwheel, for the fine adjustment. If a crank is used for tuning or another process involving numerical selection, each rotation of the crank should correspond to a multiple of 1, 10, 100, or other appropriate value. If extreme precision is required in an X-Y control, for example, in setting crosshairs or reticles in reading a map, a simultaneously-operated pair of handcranks should be used in preference to other two-axis controllers. The gear ratios and dynamic characteristics of such cranks should permit precise placement of the followers without over- or undershooting and successive corrective movements.

Figure 58: Crank Specifications



Load	Specification	Handle L. length	Handle D. diameter	R. Turning radius: Rate below 100 RPM	R. Turning radius: Rate above 100 RPM
Light loads: Less than 22N (5.0 lb) (Wrist and finger movement)	Minimum	25 mm(1.0 in)	10 mm(0.4 in)	38 mm(1.5 in)	13 mm(0.5 in)
	Preferred	38 mm(1.5 in)	13 mm(0.5 in)	75 mm(3.0 in)	65 mm(2.5 in)
	Maximum	75 mm(3.0 in)	16 mm(0.6 in)	125 mm(5.0 in)	115 mm(4.5 in)
Heavy loads: 22 N (5.0 lb) or more. (arm movement)	Minimum	75 mm(3.0 in)	25 mm(1.0 in)	190 mm(7.5 in)	125 mm(5.0 in)
	Preferred	95 mm(3.75 in)	25 mm(1.0 in)	–	–
	Maximum	–	38 mm(1.5 in)	510 mm(20.0 in)	230 mm(9.0 in)

WAGNER@1996

Table 8: Characteristics of common controls for continuous operation

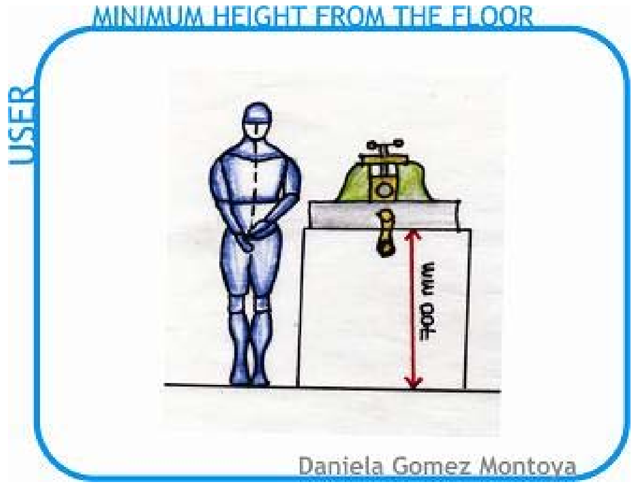
CHARACTERISTICS OF COMMON CONTROLS OF OPERATION		
CONTROL	**ADVANTAGE**	**DISADVANTAGE**
Crank	Large forces can be developed.	No effectiveness as a part of a combine control.
	Desirable limits to control movements.	No effectiveness of operating controls simultaneously with like controls in an array.
	No likelyhood of accidental activaction.	Space requirements for location and operation of control.
	Minimum effort fo the operator.	
Pedal	Large forces can be developed.	No effectiveness as a part of a combine control.
	Minimum effort fo the operator.	No effectiveness of operating controls simultaneously with like controls in an array.
		Space requirements for location and operation of control.
		Likelyhood of accidental activaction.
Lever	Large forces can be developed.	Space requirements for location and operation of control.
	Effectiveness of visually identifying control position.	Likelyhood of accidental activaction.
	Effectiveness od coding.	
Hand Wheel	Large forces can be developed.	No effectiveness of operating controls simultaneously with like controls in an array.
		Space requirements for location and operation of control.
		Likelyhood of accidental activaction.
		No effectiveness of operating controls simultaneously with like controls in an array.
Knob	Desirable limits to control movements.	No large forces can be developed.
	Effectiveness of visually identifying control position.	Likelyhood of accidental activaction.
		Space requirements for location and operation of control.

Own Elaboration

❖ Design Considerations

According to the previous information, extracted from the “HUMAN FACTORS DESIGN GUIDE”, the following analysis is presented, considering all the important aspects for the product design and dimensions:

Figure 59: Minimum Height from the Floor



Own Elaboration

The **Figure 59** represents the minimum height considered from the floor to the base of the machine. This is based on the 5th Percentile for women, as it has to be in a reachable distance for at least the 95% of the population.

Figure 60: Operation Position Stand Up

Own Elaboration

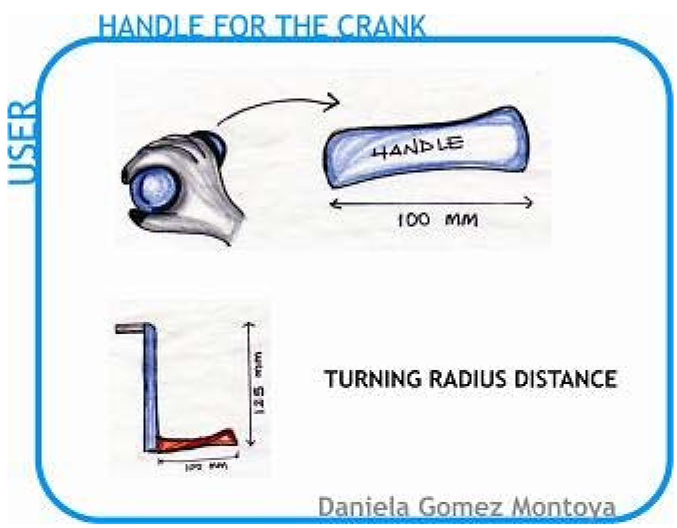
The **Figures 60** is representing the correct body position during the operation of the product standing up. This position is the most appropriate for the activities as it is less riskily in terms of illnesses; it is more effective as the gravity has a big influence on the operation and the visual angle of the product is better from the top view.

Figure 61: Hand's reach distance

Own Elaboration

The Figure 61 is showing the distance of the reach of the hand. This value is considering the minimum value for the 5th Percentile in women. That is the maximum point from the body to the crank mid point position. It is important to consider as well, that the body can be inclined a little (15 degrees) to help to the arm's movement.

Figure 62: Handle of the Crank



Own Elaboration

The **Figure 62** is illustrating the dimensions for the handle of the crank as so is for the Turning Radius. The handle dimension is based on the 99th Percentile for men, as it needs to ensure that most of the population is going to have enough space to hold the crank and operate it. The Turning Radius is based on the crank's specifications of the "HUMAN FACTORS DESIGN GUIDE".

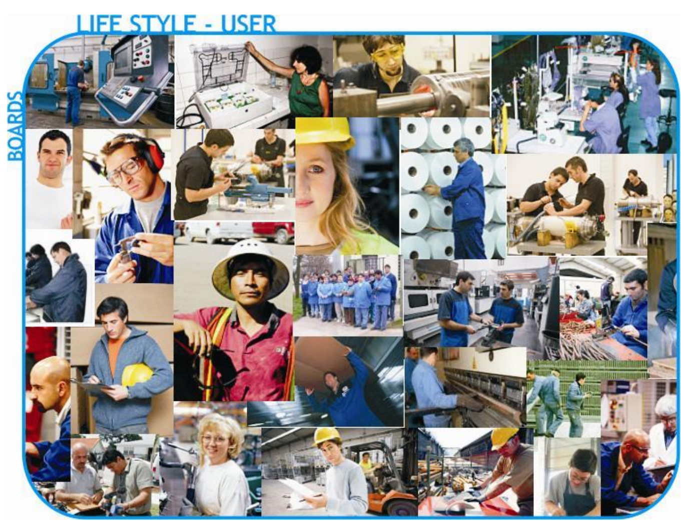
6.2.4 Shape synthesis – Product Styling

This phase of the product design describes the formal development of the product process. This phase is a brief of the meaning of the figures, shapes, colours of most of the elements of the product. The whole process is described in the **Annex No.9**.
If it is true that some of the components of the product should have an specified shape or characteristic due to it functional performance, there are others than can be interfere and designed using some of the methodologies learned during the "Formalization Emphasis Line", specially those ones that are related with the user-product interaction.

❖ Boards[32]

The visual languages of the process design are the Boards. Moreover they are a compilation of images and pictures to explain issues as the user, the context in which the project is focused and star the creation on design concepts. It is a useful tool to define the product styling, the product's message, trying to find coherence with its environment.

Figure 63: Board Life Style - User

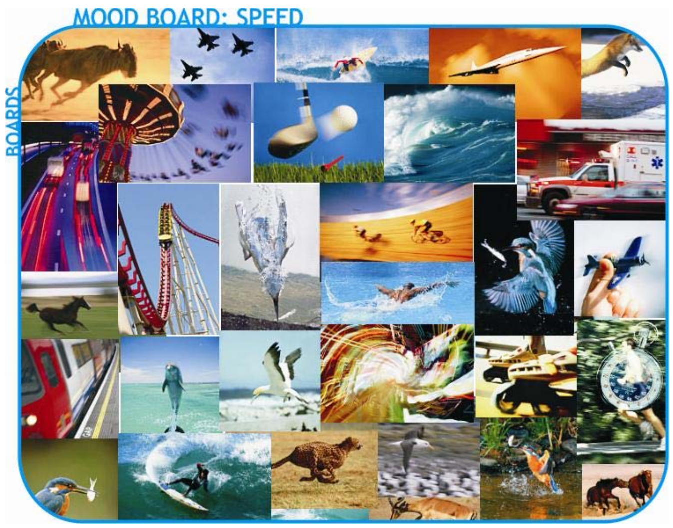


www.slidedepot.com

[32] BAXTER, Mike. Product Desing. Boards. June 1999.

This Board evidences an attribute that the product must represent. It talks about the emotion when the user uses the product. The emotion chosen for the machine is SPEED. The current activities at the company of die cutting and embossing, when the volumes of production are not big enough, are very slow because they are made by hand. It is very important to improve the times and get the activities done in a faster way. That is the reason why "Speed" is the emotion that the product wants to represent.

Figure 64: Mood Board



www.slidedepot.com

Figure 65: Context Board

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This board is a collection of images and pictures of other products used by the target group represented at the Life Style Board. These can be from different market sectors and with different functions. Products related with the user and the context.

Figure 66: Visual Theme Board

Own Elaboration

❖ Visual Alphabet

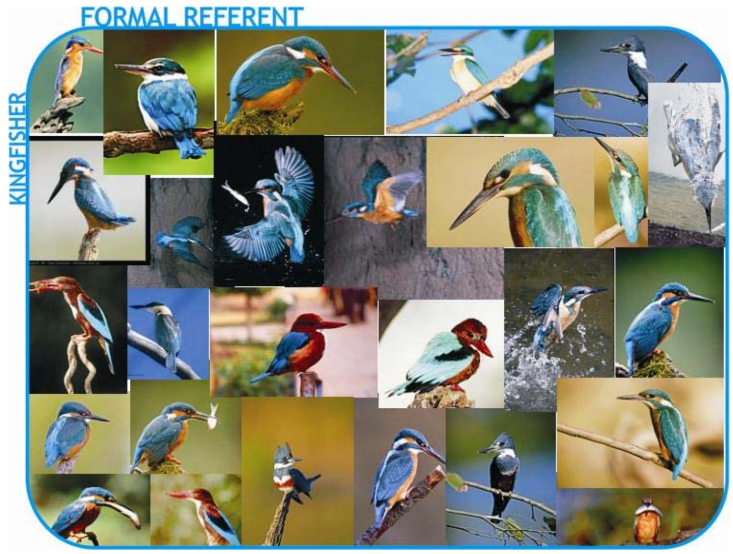
The visual alphabet is a very useful tool uses for ideas generation and alternatives of design. It uses a formal referent taken from the nature or the artificial world and elements like colours, textures, shapes, principles; which are very useful for the creation process.

o Formal Referent

As Malaysia is the context where the company MR PRINT SDN BHD is located, the referent is very beautiful and particular specie of bird typical from that region: THE KINGFISHER. Even though, the Kingfishers are found nowdays throughout many places around the world. Kingfishers live in both woodland and wetland habitats. Kingfishers that live near water hunt small fish by diving. They also eat crayfish, frogs, and insects. Wood kingfishers eat reptiles. Kingfishers of all three families beat their prey to death, either by whipping it against a tree or by dropping it on a stone.[33]

[33] WIKIPEDIA. Kingfisher. [Internet article]. http://en.wikipedia.org/wiki/Kingfisher. [January 25th 2008]

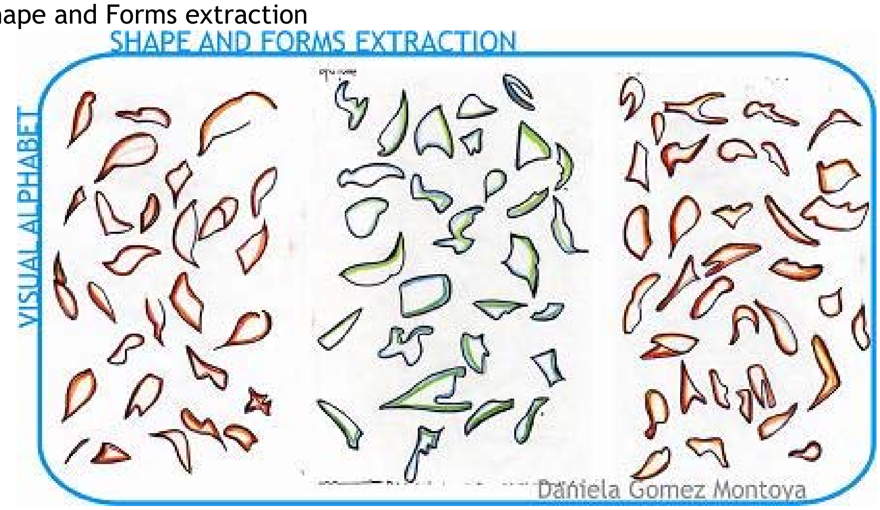
Figure 67: Formal Referent 1



www.slidedepot.com

Visual Alphabet Analysis

Figure 68: Shape and Forms extraction

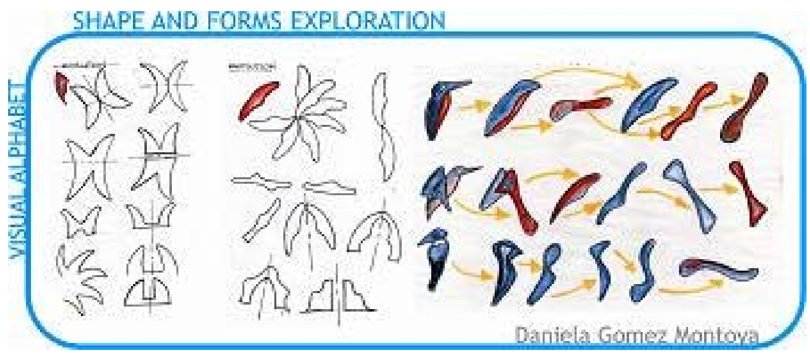


Own Elaboration

Figure 69: Colours and Texture extraction

Own Elaboration

Figure 70: Shape and Forms Exploration

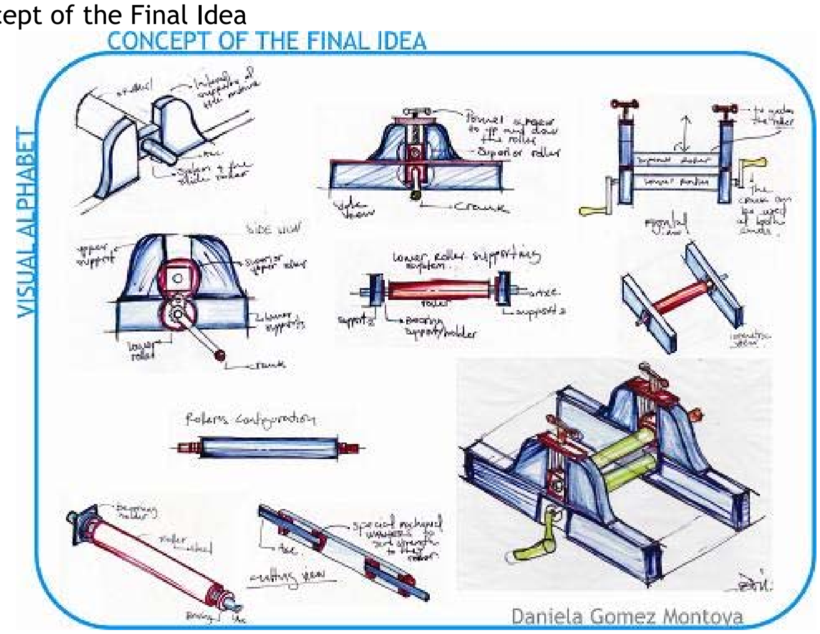


Own Elaboration

o Concept of the Final Idea – Fast hand-made Sketches

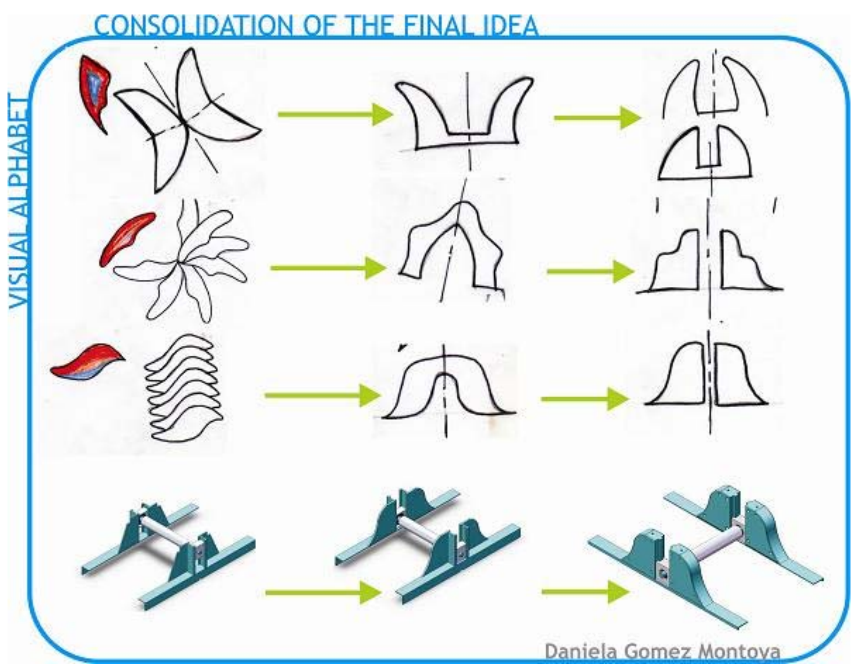
Based on the visual alphabet and considering the working structure selected on the previous section, the final and definitive idea starts to take form. During this section is presented a compilation of design and the most representative hand-drawings made to give place to the final modelation and detailed design. It is important to say that, for the project, design + production principles were combined. That means that the production facilities, machine processes and options of fabrication were highly considered when the shape was defined. After this phase, during the detail design, more refinements were done, in order to improve the final idea. Those details are clearly showed on the **Annex No. 11: Product CAD Modelation.**

Figure 71: Concept of the Final Idea



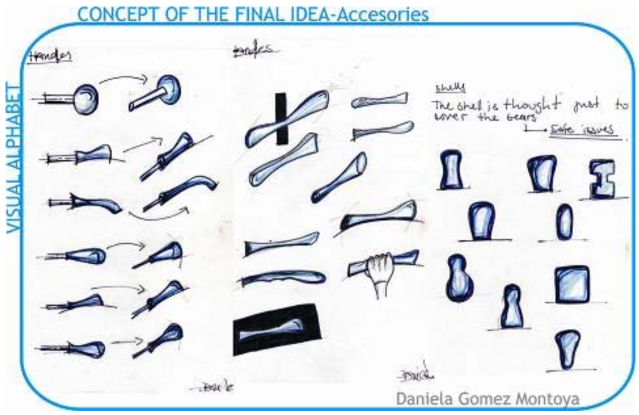
Own Elaboration

Figure 72: Lateral Supports



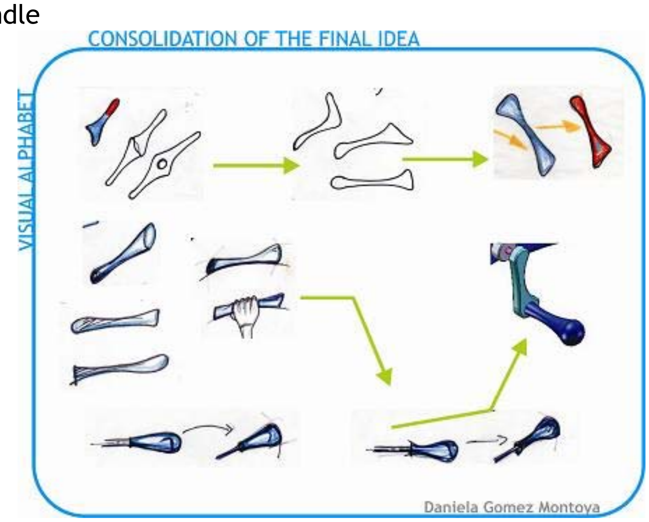
Own Elaboration

Figure 73: Accessories



Own Elaboration

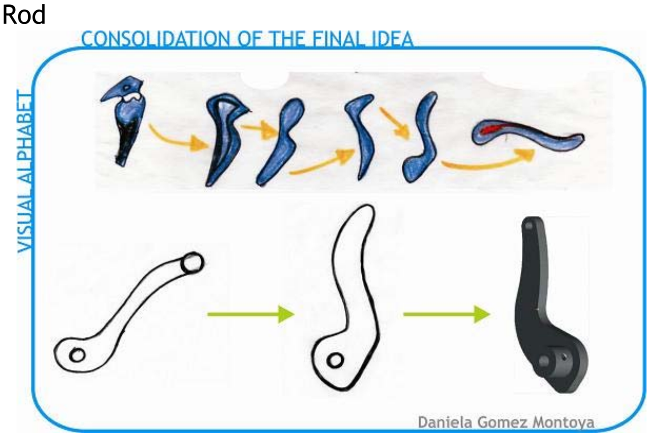
Figure 74: Crank's Handle



Own Elaboration

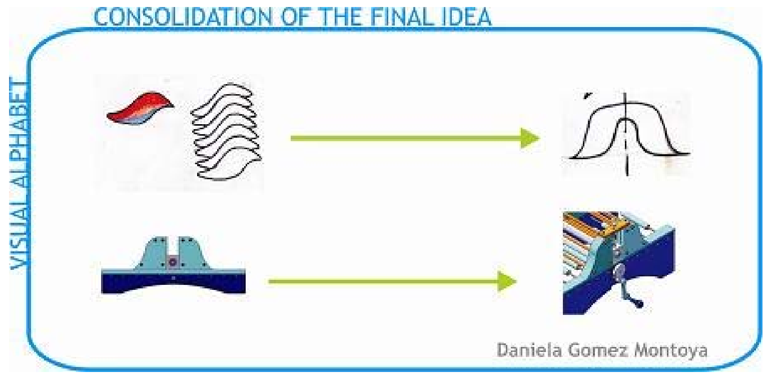
o

Figure 75: Connection Rod



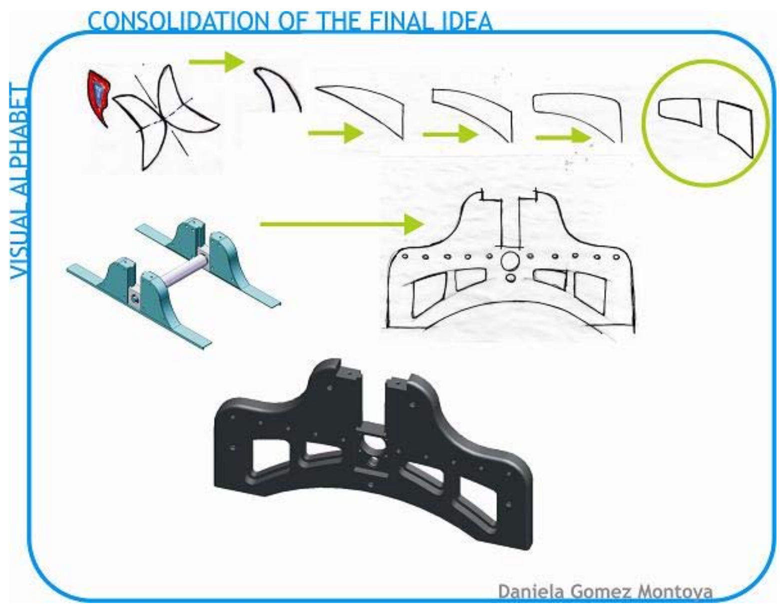
Own Elaboration

Figure 76: Lateral Support



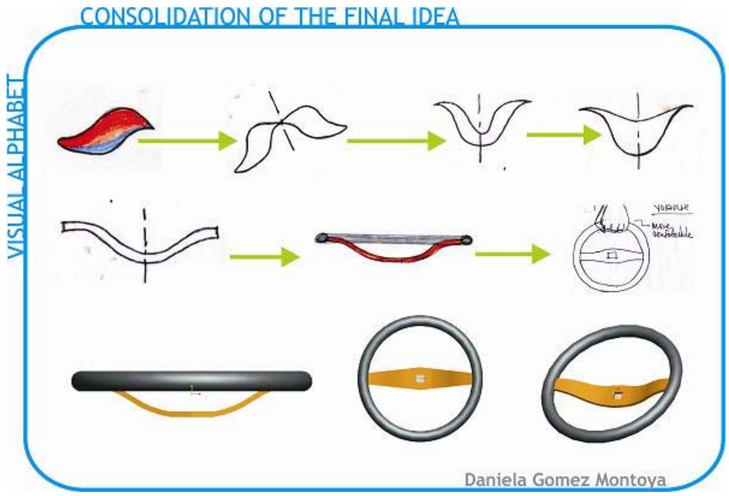
Own Elaboration

Figure 77: Final Lateral Supports



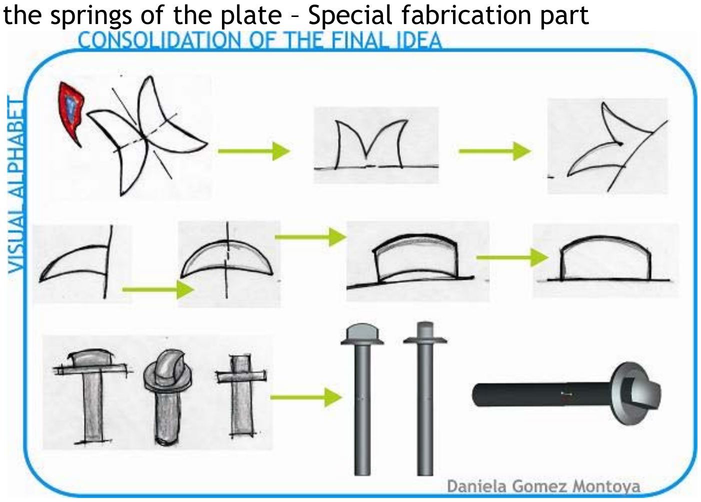
Own Elaboration

Figure 78: Lever of the Power Screw



Own Elaboration

Figure 79: Screw for the springs of the plate – Special fabrication part



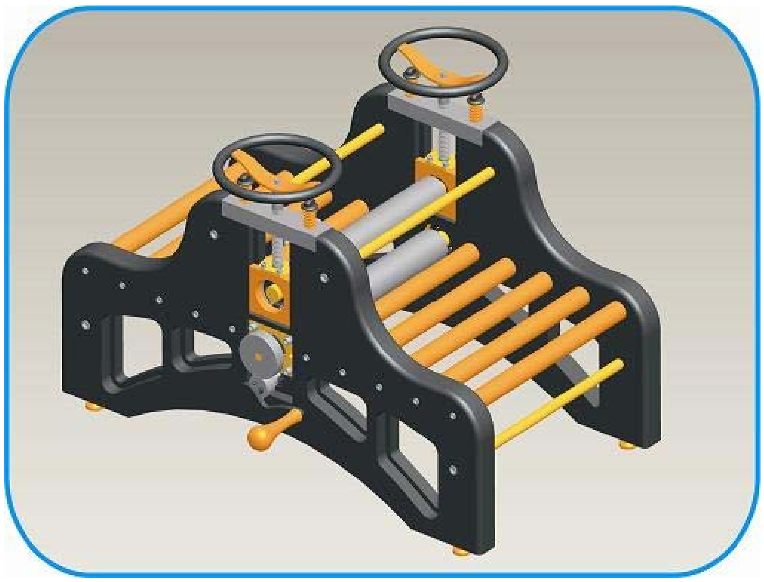
Own Elaboration

The **Annex No. 10** will show in detail the Engineering calculations considered to guarantee the function of the product. These results are next shown on the **Annex No.11** where the detail of the 3D modelation process using PRO - ENGINEER as a design Software, is presented.

6.2.5 Product's 3D Modelation

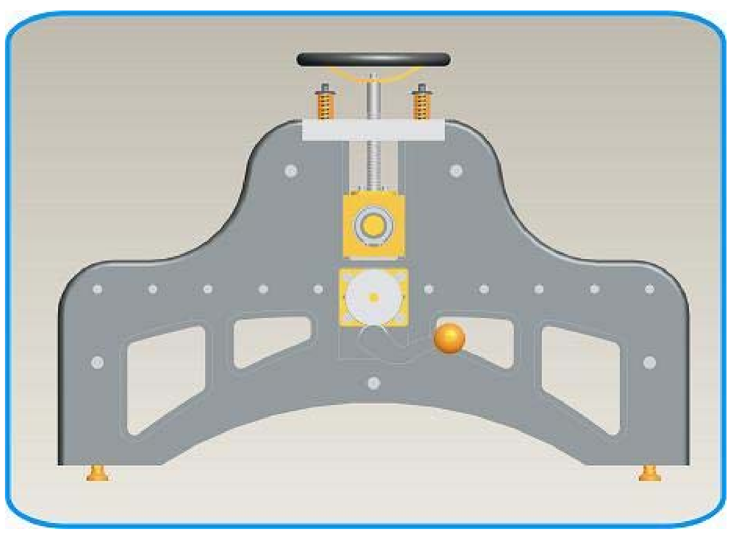
This section contains the CAD 3D modelations of the product: Parts, Sub-Assemblies, Final Assembly. For this purpose the software used was PRO-ENGINEER. According to the colors of the company's image and logo it was decided to choose the product's colors: Dark gray, orange and yellow.

Figure 80: Final Modelation Isometric



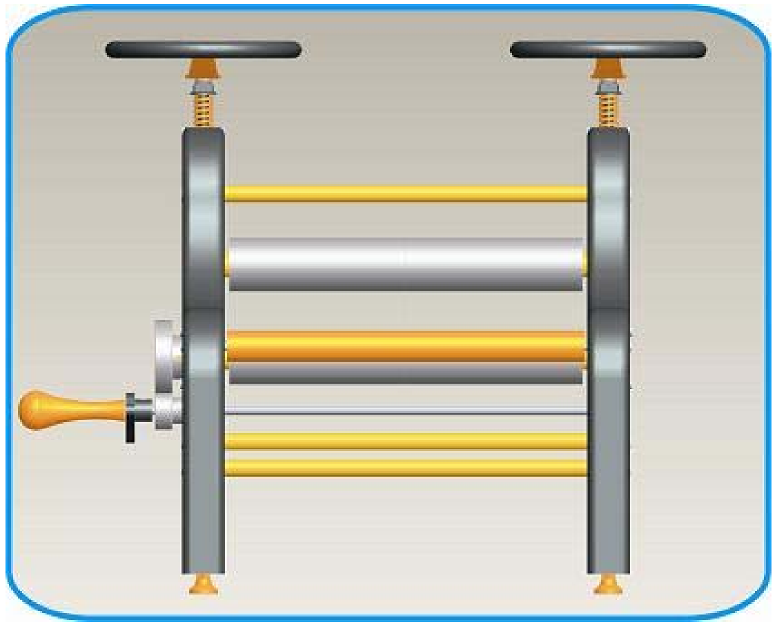
Own Elaboration

Figure 81: Final Modelation Frontal View



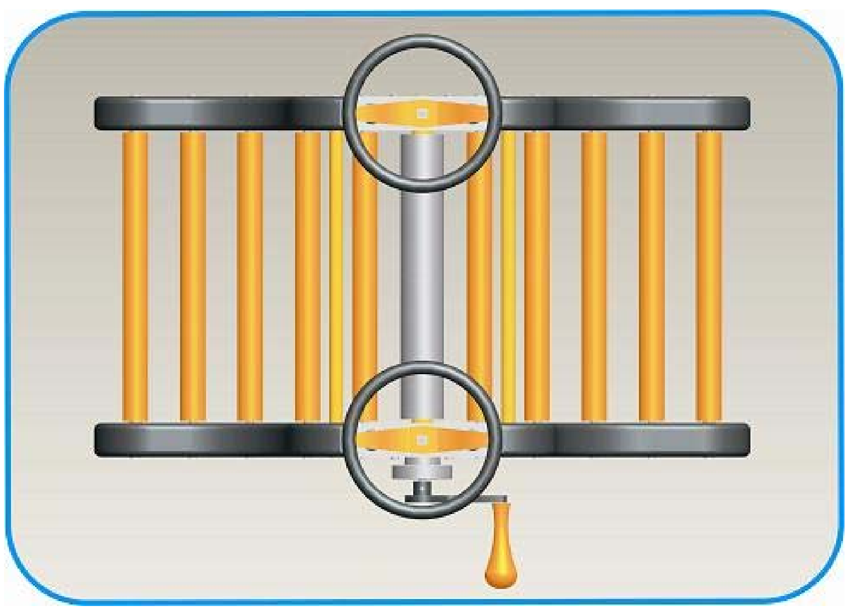
Own Elaboration

Figure 82: Final Modelation Lateral View



Own Elaboration

Figure 83: Final Modelation Top View



Own Elaboration

CONCLUSIONS

- The process of study the company, MR. PRINT SDN BHD, allowed me to find and define the specific requirements to be satisfied. One of the most important steps is to understand the translation of the customer needs to engineering requirements. The most important requirements for the company were related with the product's geometry, costs, user and safety.

- There is NOT a product with the specified characteristic that could make die-cutting and embossing at the same time, totally manual and for an industrial work. That is our market and project opportunity.

- The conceptual design steps developed allowed limiting and clarifying the Project and giving the firs idea of how the product should be work.

- The resistance of the components of the product was the most important aspect developed during the engineering phase. This phase I would say is one of the most important as the product performance depends 100% of it.

- The formal referent was the Kingfisher bird from the Southeast Asia and represents the speed and shape that the product wants to transmit.

- The result of the final product in terms of design came from the exploration of shapes and analysis of the formal referent.

- The functional model or initial prototype proved correctly that the working principle is correctly proposed and developed.

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